Mackenzie Delta Research Project

The Mackenzie Delta— Technology

By P. F. Cooper, Jr.

MDRP 2

Northern Co-ordination and Research Centre

Department of Indian Affairs and Northern Development, Ottawa

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ABSTRACT

This report is a study of ways in which modern technology could improve the standard of living of the native inhabitants of the Mackenzie Delta. Providing the amenities of modern life in that region is expensive for three general reasons: a) the more rigorous natural conditions, as compared with those of southern parts of the country; b) the numerically small and dispersed population; and c) the isolation of the area. The effect these have on different aspects of technological development is discussed for several special cases, including the provision of heat, light and electric power, water supply and sewage disposal, and transport. The difficulties of reducing the cost of these services are examined. In addition, possible applications of technology towards aiding the exploitation of the available renewable natural resources are considered. Finally, a number of specific suggestions are made for more detailed studies or applied research.

TABLE OF CONTENTS

TABLES

FIGURES

FOREWARD

The Mackenzie Delta Research Project is an attempt to describe and analyse the social and economic factors related to development in the Mackenzie Delta. Particular emphasis is being directed toward the participation of the native people of the area, and the extent to which they are making effective adjustments to changes brought about by government and commercial expansion in the north.

The individual studies within the project, and the conclusions arising from them, are being published in a series of reports. This study, MDRP 2, by P.F. Cooper Jr., was undertaken with two ends in view. First, it was to provide a description and analysis of the technology of the Delta. Comprehension of this technology is necessary for a general understanding of life and work in the area. Secondly, the author was directed to consider especially the possibilities of reducing the cost of living in the Delta through improved technology. Dr. Cooper's report deserves careful study by all who have an interest in either or both of these objectives.

A. J. Kerr,
Co-ordinator,
Mackenzie Delta Research Project.

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Credit must go to others for any virtues this report may have; its faults are my responsibility alone.

P.F. Cooper, Jr.

I

THE PROBLEM

In many respects the delta of the Mackenzie River joins southern Canada with the severer Arctic terrain typical of much of the northern part of the country. The casual visitor sees this at once in the variety of scenery to be found in a comparatively small area. At the head of the delta there are evergreen forests; as one goes farther north, these give way, first to willows, then to gently rolling tundra. The monotony of the low delta, with its river channels, islands, and lakes, is eased by a range of hills on one side, and, on the other, by the Richardson Mountains - the "snowy mountains" of Mackenzie - which furnish the traveller with a landmark for many miles. Within an area perhaps fifty miles wide and one hundred and fifty miles long there are, in addition to the delta itself, barren mountains, spots strongly reminiscent of the forests of the Canadian Shield, and stretches of arctic coast which are typical of many parts of the Canadian north.

The Mackenzie River Delta also stands between south and north from the viewpoint of renewable resources. These are relatively abundant there in comparison with other parts of the Canadian Arctic. The delta itself is an excellent habitat for muskrat and, to a lesser extent, for beaver. The Richardson Mountains provide good caribou hunting, and, for over thirty years, the tundra to the east of the delta has supported herds of reindeer. Fish are common in the river channels and in the sea, where seal and beluga occur as well. Finally, there are small, though potentially useful, stands of timber.

These resources do not compare with those generally available in an area of similar size in the south, and they may well prove too limited to support the needs of the local population. They do give the region some promise of becoming one where the native population might live on a self-sufficient basis and still enjoy the amenities common in the south. If so, the area could become the link in human terms that it already is in geographic and economic ones, and it might also provide clues toward making life easier in the more desolate regions farther to the east.

From almost every point of view, the lives of the native peoples of northern Canada are presently at a point of crisis. The materialistic side of this problem can be summarized in the words "low standard of living". The traditional, dispersed way of life - hunting, fishing, and

trapping - has proved virtually irreconcilable with aspirations to enjoy the labour-saving devices that characterize present-day life in the south. The result, all too often, is that people enjoy neither the one nor the other.

Experience has shown that it is possible to bring almost as many of the features of the southern "easier way of life" to northern regions as might be desired. The DEW Line and the Joint Arctic Weather Stations demonstrate this. In such cases money can be spent liberally, not only in developing a site but in maintaining it. In the Mackenzie Delta, technology faces the more difficult problem of finding ways of making such amenities available to the native population without the aid of continuing expenditures of large sums of public money.

There are two ways to approach this problem. We can either reduce the expense of providing services like light, water and the rest or increase personal income to overcome their high cost. The first involves a continuing search for ways of providing these services both cheaply and in small amounts. This runs counter to much of southern development; for example, the economy of electric power in the south arises in large part from the fact that the demand for it is so great that it is feasible to build very large generating stations. The second means a constant effort to develop all possible renewable resources in the Mackenzie Delta, however unpromising they may seem at first. Continuing hard, imaginative work in both these directions forms the only way by which any isolated and comparatively poor region like the Mackenzie Delta can attain a higher standard of living and take its place as a self-sufficient part of the country.

This report is a survey of the various ways in which modern technology enters into the life of the Mackenzie Delta and a discussion of the possibilities of extending their applicability and providing them more cheaply. Due to the breadth of the subject, it is impossible for any one person to treat more than a few of the problems of the region in more than a superficial summary; due to the basic nature of the needs of most of the inhabitants, it is difficult to produce any particularly original suggestions. At the least, however, the writer hopes that it may be useful to have, in one place, a description of many of the problems that arise in trying to provide the amenities that technology can offer in northern Canada. If this study is useful as an introduction to more comprehensive and more directly practical work its purpose will have been amply fulfilled.

II

THE SETTING

The utility of any technological principle or device can only be judged against the environment in which it is to be used. With the Mackenzie Delta, this environment involves not only the natural features of the region but also its inhabitants. These two elements interact in a way which determines our whole approach to the region.

There are three settlements on the geographical delta of the Mackenzie River. Two of these, Inuvik and Reindeer Station, are on the eastern side of the delta; one, Aklavik, on the western. Strictly speaking, a study of the region should be limited to these three settlements alone. Within, however, a hundred miles of Inuvik - quite close by arctic standards - there are three more settlements. To the south, Fort McPherson and Arctic Red River lie on the Peel and Mackenzie Rivers, respectively, above Point Separation. The third, Tuktoyaktuk, is on the arctic coast, some twenty miles to the east of the mouth of the East Channel. For many purposes these six settlements are treated as a unit; examples are air transport, with the service from the south going to Inuvik and the other settlements fed by local carriers, and the telephone system, which operates on the same pattern. Although this larger region violates both geographical and anthropological standards of unity,[1] it is the one that has grown up naturally and certainly will continue to form the basis of development. Accordingly, in this paper we shall consider the Mackenzie River Delta as being this larger area.

Even with our enlarged boundaries, the region is dominated by the geographical delta of the Mackenzie River. This delta is the twelfth largest in the world (Merrill _et al._ 1960:52); it extends about 150 miles from its head, at Point Separation, north to the Arctic Ocean; at its widest, it is some 100 miles across. Its most obvious feature is an almost rectangular shape, which is the result of several factors. First, there is little of the typical extensions of sedimentary deposits into the ocean, as happens with, say, the Lena and Mississippi Rivers. This seems to be due to a low overall amount of sediment in the water, which Camsell and Malcolm (1921:33) attributed, at least in part, to the large

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1. From an anthropological viewpoint, the settlements of Ft. McPherson and Arctic Red River are Indian; that of Tuktoyaktuk is typically Eskimo. Both races are present in Inuvik and Aklavik. On the other hand, speaking as a geographer, Mackay (1956:3) holds that both Richards Island and the Tuktoyaktuk Peninsula are remnants of preglacial Mackenzie Deltas.

lakes in the Mackenzie River drainage system acting as settling basins. Second, the southern end of the delta is formed by the confluence of the Peel and Mackenzie Rivers and is quite broad. Third, the southern half of the delta is confined between mountains on the west and hills and rolling uplands on the east. Even in the more northerly part of the region the eastern side of the delta is formed by the large mass of Richards Island; the eastern part of this consists of older sedimentary formations with a more rolling topography than that of the modern delta. Thus we find that the true "delta country" is mainly confined to a strip of almost constant width, between thirty and forty miles wide, which gradually curves westward as one goes downstream. The remainder of the region, apart from the Caribou Hills and the Richardson Mountains, consists of gently rolling and somewhat higher - though still quite flat - country.

In this area the soils and the weather are the natural conditions that most strongly affect engineering techniques and, more broadly, technological development.

The first problem with the soils is their nature. The low lands of the present delta are almost entirely silt. With few exceptions, the whole region seems singularly lacking in suitable materials for construction. There are a very few small riverine deposits of gravel in the delta, of which that at Point Separation is the chief example (Henoch 1960:37). The situation is not much better in the uplands on the east side of the delta. The Paleozoic outcroppings near Inuvik are overlain, farther south, by fine-grained glacial deposits; only when we come to Arctic Red River do we find substantial deposits of gravel. To the north, the Caribou Hills seem to be primarily fine-grained sediments with only small deposits of gravel. The older Pleistocene deposits of Richards Island and around Tuktoyaktuk are also primarily fine sands and boulder clay (Mackay 1963:16). Substantial gravel deposits are rare. The largest proven ones are at Tuktoyaktuk and Inuvik, and both of these are limited in quantity. In building the eight-mile road from the townsite of Inuvik to its airport, it proved impossible to locate usable gravel deposits over much of the distance, and construction plans at Tuktoyaktuk are recurrently threatened with expected shortages of material.

Lack of material is not the end of the problems construction projects must face; the Mackenzie Delta, like most of the rest of northern Canada, is underlain by permanently frozen ground, or permafrost. In this region, the ground is permanently frozen to a depth of several hundred feet; the "active layer", that within which seasonal thawing takes place, is shallow, being, in typical undisturbed areas, about two to three feet thick (Pilhainen 1961; 14).

Under certain conditions - in particular, when the bearing strength of the soil is the same whether it is frozen or thawed, the presence of permafrost can be neglected. This does not happen in the Mackenzie Delta. At all the settlements the amount of water in the soil is large; frequently it appears as "ice lenses" or "ice wedges", large buried masses of practically pure ice. Under such circumstances, thawing can lead not only to a loss of bearing strength, with consequent settling of any structure, but also to drastic slumping of the soil. The heat to cause this thawing can be transmitted into the ground in a variety of ways. Two of the most common are constructing a heat source, such as a poorly insulated building, in contact with the ground, or disturbing the natural cover of vegetation. This last leads to a change of the thermal balance at the surface and a considerable increase in the thickness of the active layer, at Inuvik from the two to three feet in undisturbed ground to about six.[1] The prevention of any such transfer of heat is one of the basic problems of construction in any region like the Mackenzie Delta.

A minor point about the soils is that the mean annual ground temperature, several feet below the surface, is noticeably higher than the mean annual air temperature (26° F as against about 15°F). This difference is not confined to the Mackenzie Delta; it arises, at least here, because the soil cover is wet and dark and has a greater ability to absorb and transmit heat in the summer; in the winter, when it is dry and also covered with snow, it is a better insulator. As a result, more heat is absorbed in the summer than would be lost in the winter if the average ground temperature were the same as the average air temperature, and the average ground temperature is higher. In this region, this phenomenon can be troublesome in such practices as using the ground as a natural refrigerator. In theory, it could also provide a winter source of heat, but it is difficult to see how this could be done economically.

Although the peculiarities of the soils may enter into only a few engineering applications, albeit important ones, the climate influences almost every side of everyday life. Two basic factors determine the climate of the Mackenzie Delta: first, its high latitude, and second, the fact that the ocean it lies on is cold, not, as in the case of Scandinavia, warm.

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1. Hill, R.M., pers. communication

Because of the high latitude, the sun never attains a great elevation. This is somewhat compensated for by the fact that the days in summer are long. The Mackenzie Delta lies entirely within the Arctic Circle; accordingly, there is a period in the summer when the sun never sets; at Inuvik, this period is eight weeks long. Civil twilight[1] lasts all night for a period at either end of this, so that it is light all the time from the beginning of May until the second week in August. The region is still far enough south, however, that there is considerable twilight in the corresponding winter period when the sun is always below the horizon; at Inuvik there are about five hours of civil twilight on the shortest day of the year.

The fact that the sea is cold means that it has little moderating effect on the seasons. As a result, we find that the region has warm summers and quite cold winters - a typical continental climate. The transitions between these seasons are abrupt, as the average temperatures given in Fig. 1 show.

For many purposes, the coldness of the climate can be gauged by the number of degree days;[2] in particular, these units have proved to bear a direct relationship to the amount of heat needed to keep a building warm and are widely used in estimating the amount of fuel needed for heating purposes. Table I gives yearly totals of degree days for Mackenzie Delta settlements in comparison with more southerly places.

The length and coldness of the winter mean that the river channels and the ocean are covered with ice for most of the year. This is of particular importance in the Mackenzie Delta, where there is no extended road network and where the river channels are used widely for travel, both by boat and on the ice. Table II gives mean dates for freeze-up and break-up. There are three and a half to four months - June to September - during which boat travel is possible. In November the ice on the river and the lakes is generally thick enough for travel by surface vehicle, and it remains so until May.

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1. Civil twilight is the period during which the sun's centre is not more than 6° below the horizon. "The degree of illumination at the beginning of morning and end of evening civil twilight is such that the brightest stars are just visible, and terrestrial objects can be easily distinguished." (The Air Almanac: A9 f.)

2. There are as many degree days in a single calendar day as the number of degrees by which that day's mean temperature falls below $65^{\circ}F$.

Another important climatic factor is the amount of precipitation. Like the rest of arctic Canada, the Mackenzie Delta is dry; Fig. 2 gives the average precipitation per month (measured as rain) for Ft. McPherson, Inuvik, and Tuktoyaktuk. Fig. 3 gives the average depth of snow during the winter months. There are only four months during which we can expect the ground to be bare; further, as Mackay has pointed out (1963:154), the average depth of snow diminishes as we go northward from the head of the Delta to the coast. Due to the winds and the dryness of the snow, deep drifts can be formed, so these "average" depths do not give a true picture of the extent to which small hummocks and the like disappear during the winter months.

In this region there is a total population of some four thousand; approximate figures for the different settlements are given in Table III. The fact that the Delta is the meeting place for peoples in the same way that it is the boundary between the Arctic and Sub-arctic gives us two settlements - Ft. McPherson and Arctic Red River - which are predominantly Indian, one, Tuktoyaktuk, a coastal Eskimo settlement, and two, Inuvik and Aklavik, where both peoples are present.

The settlements of the region still reflect the original reasons for their existence. A short summary of their history, accordingly, is useful in understanding their peculiarities and seeing the different demands of the region.

The first settlements were associated with what has always been the major industry of the region - trapping and fur trading. Although various explorers, starting with Alexander Mackenzie in 1789 and including Sir John Franklin, visited the region before 1840, commercial fur-trading was not established in the region until then. In that year Ft. McPherson was founded; it was originally some four miles farther up the Peel River than its present site, to which it moved in 1852 (Henoch 1961:88).

In the nineteenth century, both Indians and Eskimos traded at Ft. McPherson. Towards the end of the century, the Eskimos moved northward, perhaps as a result of increased opportunities for contact with the whalers. The eventual result of this migration was the founding of a second trading centre in 1912, which became the present town of Aklavik. Furthermore, as the result of religious differences, the settlement of Ft. McPherson split up in the late nineteenth century, leading to the formation of the settlement of Arctic Red River.

Although fur trading caused the appearance of three of the six settlements of the region, it did not change the fundamental nomadic life of the people and did not directly create the severe economic problems that have arisen with life in the present-day settlements. It did, of course,

Fig. 1

Monthly Mean Temperatures for Settlements in the Mackenzie Delta. (Source: Publications of the Meteorological Branch, Department of Transport.)

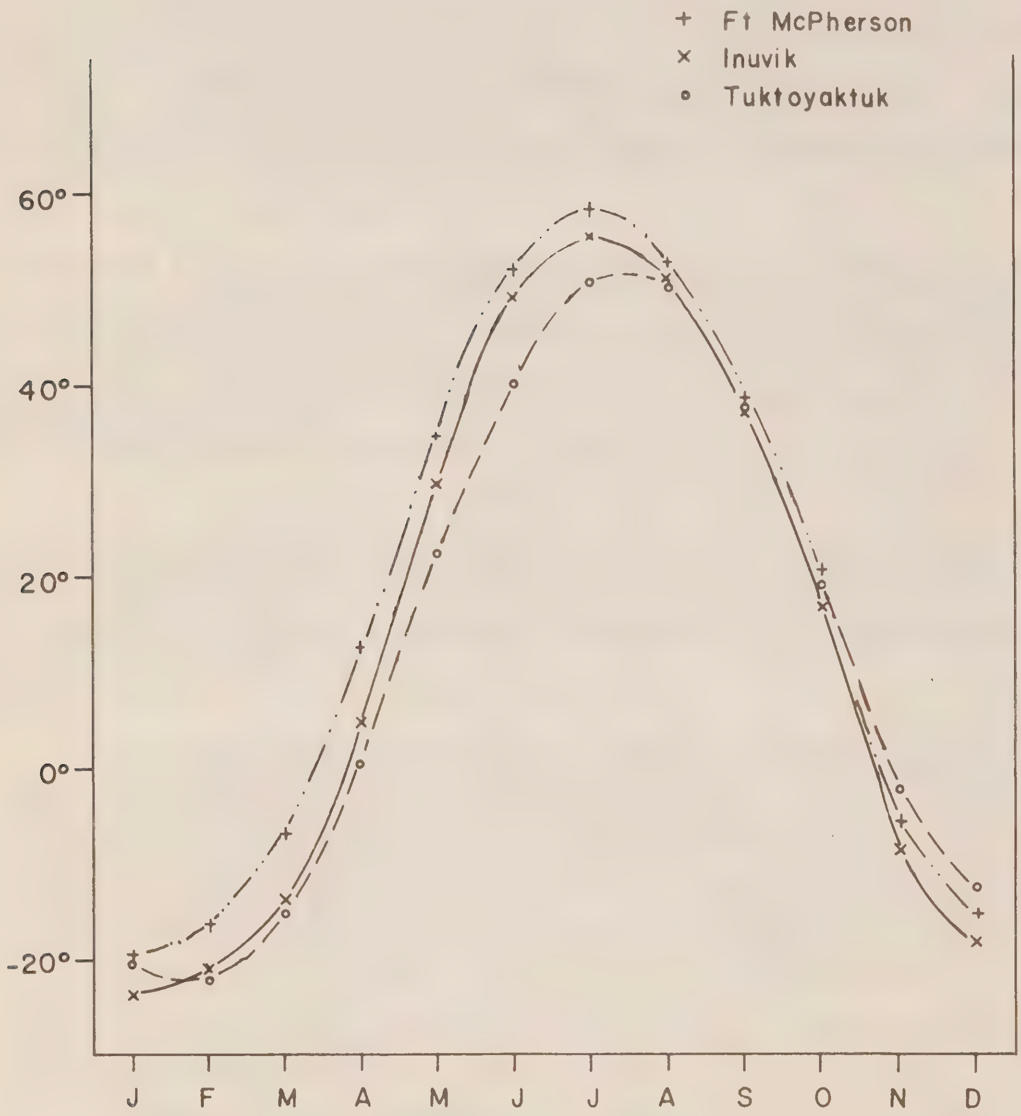


Table 1

Annual Degree Days

Aklavik	18017
Ft. McPherson	17403
Inuvik	18584
Tuktoyaktuk	19283
Halifax	7361
Montreal	7899
Toronto	6827
Winnipeg	10679
Vancouver	5515

Source: except for Inuvik and Tuktoyaktuk: Circular CDS 5-64, Climatology Division, Meteorological Branch, Department of Transport. Inuvik and Tuktoyaktuk based on 10 - 13 years' data, 1950 - 1966.

Table II

Mean Dates of Freeze-up and Break-up

	Freeze-up	Break-up	Years of record
Ft. McPherson	14 October	24 May	7 - 9
Aklavik	12 October	31 May	18 - 19
Inuvik	23 October	31 May	3 - 6

Source: Circular 4116(Ice 17), Meteorological Branch, Department of Transport

Table III

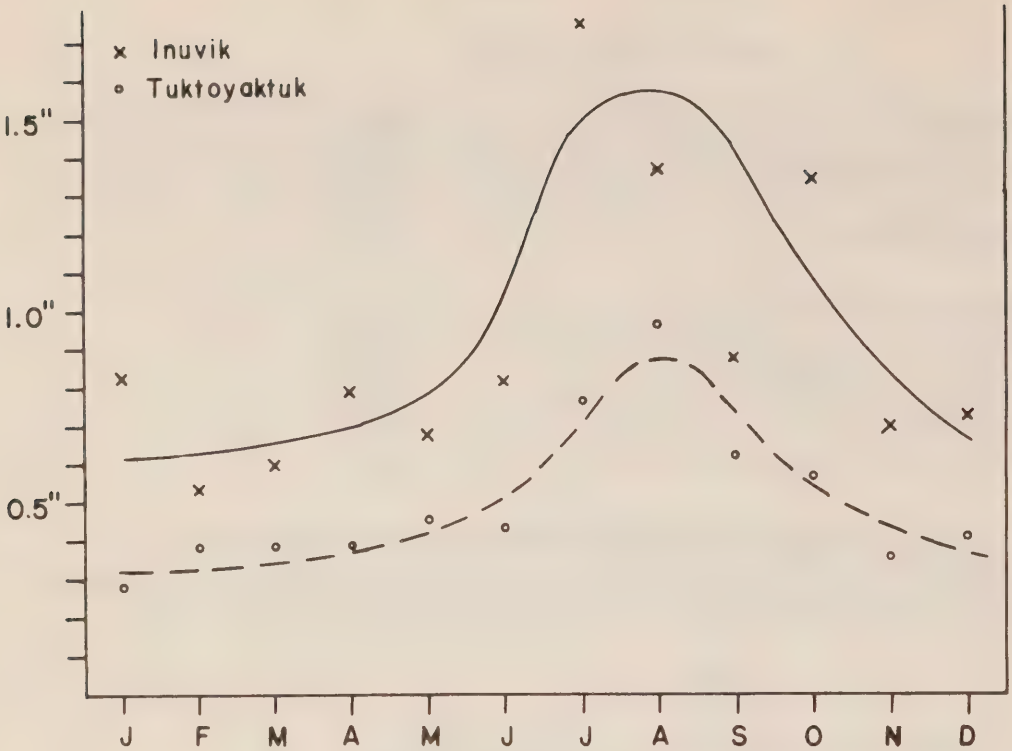
Population of Mackenzie Delta Settlements, 1965

	White	Metis	Eskimo	Indian	Total
Aklavik	145	60	280	150	635
Arctic Red River	5	21	-	83	109
Ft. McPherson	70	80	6	550	705
Inuvik	1367		646	245	2258
(Hostels)*	(102)		(270)	(114)	(486)
Reindeer Station	9	-	60	-	69
Tuktoyaktuk	40	19	400	6	465

*Schoolchildren resident in hostels.

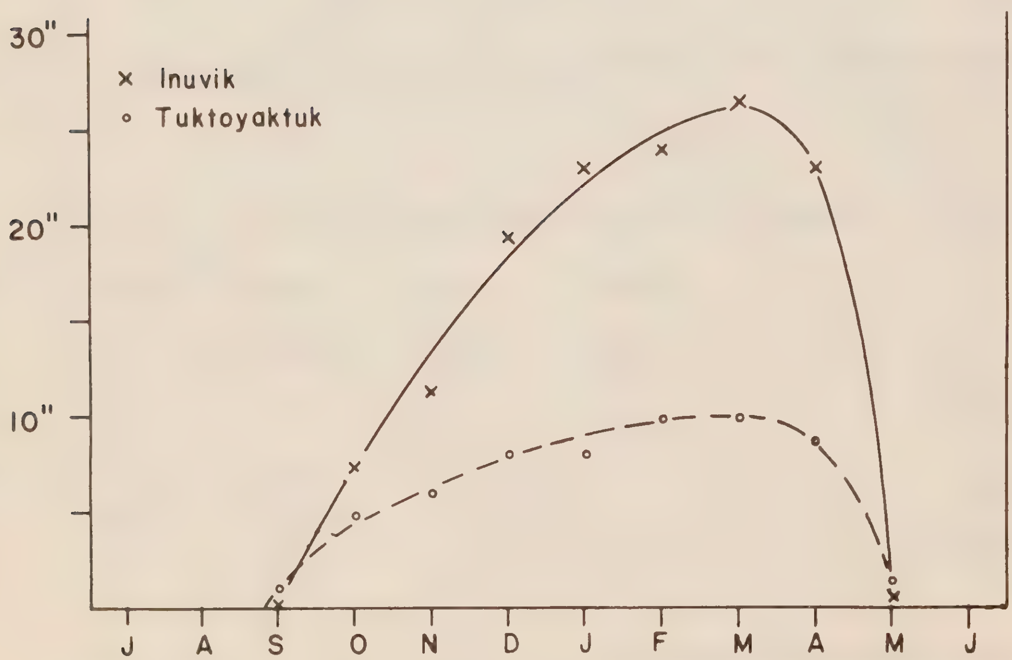
Source: Area Administrators, Department of Indian Affairs and Northern Development, at Aklavik, Ft. McPherson and Tuktoyaktuk, and R.M. Hill, Inuvik Research Laboratory.

Fig. 2



Monthly Average Precipitation (measured as rain) for Inuvik and Tuktoyaktuk. (Source as for Fig. 1).

Fig. 3



Average Depth of Snow on the Ground at the End of Each Month at Inuvik and Tuktoyaktuk. (Source as for Fig. 1.)

lay their seed, since it brought fire-arms into the area, and so may have upset the balance of nature, though not to the extent that has happened with the caribou farther east; it made the local inhabitants dependent on goods imported from the south; and it led to the use of money in this part of the Arctic long before this happened elsewhere (Rasmussen 1927:293).

The coming of the whalers to the Beaufort Sea in 1890, though it led to no settlements in the region of this report[1], did have a drastic effect on the people. Diseases were introduced which led to a virtual depopulation of the Mackenzie Delta of Eskimos; this, in turn, led to a wave of immigration from Alaska. The whalers also increased the use of firearms and left behind them many people of mixed blood (Jenness 1964: 13 ff.).

The most recent change has also been the most profound; it is that from a nomadic hunting and trading economy to a life of which the greater part is spent in a settlement. The beginning of this may perhaps be set in 1934 with the foundation of Tuktoyaktuk as a trans-shipment centre between river boats and the ocean-going vessels supplying the settlements to the east. Although Tuktoyaktuk harbour was a favoured spot for many years - Stefansson stayed there in 1906-07 (Stefansson 1923: 133 ff), and in 1924 Rasmussen counted six houses there (Rasmussen 1942:44) - it did not become a permanent settlement until this later date. Since then, a gradual centralization of coastal facilities has occurred: the trading post at Herschel Island was closed in 1938 and that at Stanton in 1954 (Abrahamson 1963:8). The Eskimos' movement to Tuktoyaktuk intensified in 1954 with the construction of the DEW Line site there, and this date can be considered as a clear dividing line in the coastal Eskimos' change from a nomadic life to a more settled one.

Chronologically, the settlement at Reindeer Station was the next to be founded. This community is set apart in a major respect from the other settlements of the Mackenzie Delta; it is the headquarters of the reindeer herding project. With the exception of the school teachers, the Hudson's Bay Company store manager, and their families, the population consists solely of men who work for the reindeer project and their dependants. In other words, Reindeer Station is virtually a "company town" exploiting an agricultural resource of the region. It does resemble the other settlements

1. The whalers' usual wintering grounds were to the west of the Mackenzie Delta, and the only permanent Canadian settlement in this part of the world to result from whaling was also to the west, at Herschel Island.

in that the Hudson's Bay post there serves as a trading centre for some 75 people who live in neighbouring parts of the Delta. On the whole, though, it lies somewhat outside of the scope of the present paper, and we shall seldom have occasion to refer to it later.

The newest settlement is Inuvik. Since this town embodies so many technological features which are unique in the region, if not in all of northern Canada, it is worthwhile describing it in somewhat more detail.

For many years Aklavik was the centre of government activity for the region. By the early 1950's it was, in summer, a settlement of some 1500 people, and it became apparent that it was not suitable as a governmental centre on a long-term basis. Aklavik's site is low and subject to occasional flooding at break-up; the ground is silty and poor for construction; and there is no place for a year-round airstrip suitable for heavy aircraft.

At first, it was hoped that a new town could be created which would replace Aklavik entirely. From the point of view of construction, however, the most satisfactory site for this new town, was found to be on the east side of the Delta. The hunting and fishing are both poorer there; as a result, people with permanent or semi-permanent wage employment have moved to the new town - Inuvik - while Aklavik has reverted to a centre for people who live more off the land.

From the point of view of technology, Inuvik is the most important settlement of the Delta. It was consciously designed to demonstrate the possibility of building a northern town with as many of the features of our urban civilization as possible; the design was carried into practice without stint. Inuvik is important not only as physical proof of the feasibility of many design concepts but also because it has provided a vast body of experience which is of immeasurable use in trying to raise the standard of living in other communities where money may not be as easily available as it was in the building of Inuvik.

A word of caution must be given here. Inuvik was conceived, as we have said, as a government centre: its primary purpose was to be the provision of schools, a hospital, federal buildings, and the various ancillary functions - housing, a laundry, and so on - that these entail. The approach used was to treat part of the town, basically, as a large industrial plant. This is a valid approach and has unquestionably been realized with a considerable degree of success. It inevitably results, however,

in a centralization of facilities and also in a certain lack of flexibility in expansion. Neither of these might be practicable or desirable elsewhere. This overall approach to the planning of Inuvik must always be borne in mind, both before hastening to criticize the town and before planning a carbon copy of its facilities for use elsewhere.

More generally, Inuvik has created employment, both during its construction and later; thus, in the same way as the building of the DEW Line, it has contributed to bringing the natives of the region to the settlements. In a sense, Inuvik is the "city" of the Delta - the place where people from the entire region gravitate in search of employment. This obvious tendency towards living in a settlement as much as possible is of great importance in the question of providing suitable facilities there.

The main source of steady employment is at present at Inuvik. There are few permanent jobs elsewhere, and the majority of the people who live in the other settlements have to live, in part at least, off the land.[1] Though the trend towards living in settlements seems irreversible; this situation may last for many years. As a result, although the greater part of the following chapters will be spent in considering life in the settlements, we shall also treat possibilities of making life in isolated camps easier.

Before proceeding to a specialized discussion of utilities, it may not be out of place to pause and summarize the general appearance of the delta. This can, perhaps, be done through describing an airplane flight the author took across the delta, from Aklavik to Inuvik, late one winter afternoon. As he left Aklavik, the mountains of the Richardson Range were hidden in clouds behind him. Below lay the delta itself with its dark spruce trees standing out in contrast to the white of the ice-covered channels and lakes. Across the Delta the row of hills which lines its eastern side was visible; below there the lights of Inuvik sparkled. Far to the north the lights at Reindeer Station could just be seen. Beyond the horizon were other islands of light - Fort McPherson and Arctic Red River, some eighty miles to the south; to the north, Tuktoyaktuk lay on the shore of the frozen sea.

In many ways, these towns are isolated and primitive; in others, remarkably advanced. These are the details to which we now turn.

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1. As an example, it has been estimated (F.S. Bailey, pers. comm.) that approximately 60% of the native population of Aklavik goes trapping for an average of five weeks in the spring of each year; about 40% may go fishing during the period mid-August to freeze-up.

III

Technological Aspects of Life in the Settlements

In general terms, the principal ways in which technology has made our everyday life easier can be easily listed. Probably the most fundamental is the cheap provision of heat and light. Electric power, in some respects an extension of these, has become vital; we rely, particularly in cities and towns, on convenient water supply and sewage disposal. The development of cheap, easy ways of insulating buildings is important in any cold climate. Other general advantages arise from economic, quick transport, and, more generally, from the possibility of rapid communication between places that are far apart. Beyond this are matters which, though of great importance, do not necessarily come up every day - the provision of better medical service is an example - and then the many ways, of which movies and television are the most obvious, in which technology has contributed to the enjoyment of leisure time.

Even though we simplify the problem by saying that these last are only peripheral to the matter of the present paper, a coherent description of the present development of the technological facilities of the Mackenzie Delta is difficult. There are two main sources of complication.

First is the striking difference in the extent of the amenities of southern life available to administrative and technical people from the south and those the rest of the population can obtain. The width of this gap is clear to every tourist, no matter how short a time he may spend in the region. In every settlement government workers can enjoy a way of life that is quite comparable to that of southern Canada; the remainder of the population - native inhabitants or southerners working for private enterprise - generally cannot do so or can only at great personal expense.

This double standard of living is the direct evidence of the region's challenge to technology: how to make familiar utilities available without the present high cost and without a continuing wholesale subsidization of which the present proposed subsidy of electricity would be but a part. It tends to make any description of available facilities difficult, for it is natural to dwell on the technologically better developed side of life and to forget that in almost every instance this side is available to only a part, frequently only a very small part, of the population.

Further confusion arises from the fact that it is not practicable to separate the various facilities into watertight compartments to simplify describing them. Even in the south this cannot be done completely; for example, the problem of heating a building is closely bound up with that of insulating it. In the north the situation is worse. Let us consider supplying water and removing sewage. In the south, this can be done by burying pipes below the frost line. In northern regions, such a solution is impractical; heat must be supplied to any such piping, whether buried or above ground. The result is the combination of water and sewer services into one unit, such as the above-ground boxes called "utilidors". In Inuvik the utilidor also supplies building heat, thus increasing the number of utilities that are present in a single unit.

The rest of this chapter will give as straight-forward a description as possible of these various utilities. In each case, we shall try to show what the native inhabitants of the Delta have at present and then describe the various ways in which attempts have been made to bring in a higher standard of living. In so doing we shall also try to point out the places where future study could be spent most profitably.

1. Heat

Obviously, more fuel is needed to heat buildings in the north than in a more temperate region. Degree days are a way of putting this into more quantitative terms; as Table I shows, nearly three times as much fuel would be needed to heat a house in Inuvik as an identical house in Montreal.

This fact puts a premium on using a fuel that requires as little labour to obtain as possible. Most of the native population of the Mackenzie Delta uses wood. This is particularly true outside of Inuvik. At Arctic Red River and Ft. McPherson almost all the native inhabitants heat their houses with wood; even at Tuktoyaktuk, north of the tree-line about two-thirds of all private housing is heated with wood - in this case driftwood.[1] In Aklavik in 1965 about 34 of 55 private houses were heated by oil. Not counting 14 welfare houses there, only eight Eskimo and three Indian families used oil regularly, though many more bought oil at times.

The basic contribution of technology to this problem has been to make so-called "fossil fuels" - coal, oil, natural gas - readily

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1. Recent information (J.D. Flynn, pers. comm.) indicates that this last source of fuel may be being used up faster than it is being replenished.

available and easily usable. In the Mackenzie Delta, fuel oil is used to heat government buildings as well as the fraction of native houses mentioned above. This oil comes from Norman Wells, some 500 miles up river from Inuvik, and is brought downstream by barge.

Heat is produced in a variety of ways from oil. The most complex is at Inuvik, where superheated water is generated in a central plant and distributed to the buildings forming the core of the town: the school, hostels, government housing, the hotel, stores, and administrative buildings. Elsewhere, there is a wide variety of heating equipment. Oil burners with forced air systems and similar conventional equipment are found in government buildings throughout the area, and methods of heating range from these through oil ranges and space heaters to the home-made stoves which can be found in some of the native houses.

Oil heat has a serious drawback: the high cost of fuel oil. Though the region is fortunate in being only five hundred miles from a refinery - and so escaping the high transport costs that apply in other parts of the Arctic - oil is not cheap by southern standards. For example, the retail price of fuel oil at Inuvik is \$0.28 per gallon (of which transport costs account for about seven cents); at Aklavik it is \$0.311 per gallon, and at Tuktoyaktuk \$0.45. This is to be compared with \$0.185 at Ottawa.

Combining this difference in price with the fact that we need two and a half to three times as much fuel to heat a house in the Delta as in a city like Montreal or Ottawa, we begin to see the true magnitude of the heating problem in the north. We must spend five to ten times as much in the Mackenzie Delta as we would expect to in an eastern city. Even a small house is expensive to heat. As examples, Abrahamson (1963: 27) estimated that at Tuktoyaktuk a small, well-built log house, 16 ft by 28 ft, would need about 1350 gallons of fuel oil for one year's heating, at a cost of over \$620.00. Similarly, two prefabricated "512's" (houses 16 ft by 32 ft in plan) used 1391 gallons and 1466 gallons of oil during 1965.[1]

The problem of reducing the expense of heating is acute and, in fact, probably the single most important one of those faced by technology in the Mackenzie Delta. It is also probably the most difficult to solve.

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1. J. Roska, pers. comm.

Obvious suggestions are to reduce the cost of transport or, by increasing the amount of building insulation (within the limits imposed by added costs of construction), to reduce the amount of oil needed. We shall return to these later, but the figures gives here already show how difficult it would be to reduce heating costs by these means to the point where they became competitive with those in the south.

A different approach has been used at Inuvik. There, by combining the heat loads of many buildings into a central power plant, it has proved feasible to use a lower grade of oil, a residual oil, available wholesale at $0.17 per gallon. This is a substantial saving; as a further advantage, bringing all the heating units together into one place substantially reduces the risk of fire.

The arguments against the use of such heating plants as a standard method of heating settlements are strong. We have already seen one such a plant is comparatively inflexible in design. Experience in Inuvik has shown that it is not easy to make the continual extensions to, and changes in, service that a town requires. Furthermore, the costs of the heat distribution system are high, for; there is a substantial heat loss in the utilidors. Careful design might reduce the magnitude of these problems, but it cannot eliminate them. All this diminishes the advantages of a cheaper fuel.

Other ways out of this situation involve finding an alternate source of heat energy. Certain fuels are available locally; of these we have already mentioned wood. The principal disadvantage of wood is that the labour involved in gathering it is extremely large. It might be possible to devise a way of burning wood that would require the individual to spend less time. Although technology could enter into the solution of this problem, it is more particularly one which needs administrative study and handling.

Other potential local fuels seem even less promising. A coal deposit northwest of Aklavik was worked for several years and the coal brought to Aklavik by barge.[1] The coal is of low grade and the site is sufficiently inaccessible that the venture proved uneconomic. It is conceivable that with better methods of transport its utilization might again be feasible. Peat is distributed throughout the region and might be used for fuel, as has been suggested for the similarly placed Lena Delta in northern Russia. Apart from the difficulty of extracting peat from frozen ground, the prevailing climate does not lead to the formation of peat of great heating value (Kazakov 1956: 3).

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1. C.L. Merrill, pers. comm.

Apart from these, current exploration may lead to the discovery of extensive oil and gas fields near the Mackenzie Delta. Here again the difficulties are economic. Experience at Norman Wells has shown that the current demands of the whole region it serves - much of northwestern Canada - are insufficient to allow the cheap production of fuel. If, however, large enough fields were found so that it was practical to export oil, this might no longer be true.

Finally, we have the possibility of heating by electricity. At present, with almost all the electricity of the region being produced by diesel generators, this cannot be economical, as the following argument shows. A diesel generator converts about one-third of the heat content of the oil to electric power, while with a space heater in moderate repair about two-thirds of the heat goes to heating the building. Thus, where the same oil is used for both purposes, electric heat would cost twice as much as gas heat even if there were no other expenses in power generation than that of the oil. Even the cheaper fuel used at Inuvik cannot overcome the lower efficiency of the process of generating electricity.

If hydro-electric power were available, this line of reasoning would no longer be true. We shall return to hydro-electric power in the next section; here we shall only point out that one gallon of fuel oil contains the equivalent of 46.5 kwh of electrical energy. Thus even at Tuktoyaktuk, where oil is most expensive, electricity would have to cost about one and a half cents per kwh to be on a competive basis. The capital investment in a hydroelectric plant is so large, the settlements so scattered, and the foreseeable total electric demand so small that such a rate seems unlikely.

In the short-term future the general problem of cheap building heat seems most difficult. There is still one side of the picture that we have not touched on and which deserves further study: the utilization of the waste heat which arises in the generating of electricity. Of the 65% to 70% of the heat content of the fuel that is lost in this process, about half goes into the exhaust gases and half into the coolant. Unfortunately this heat is not in a particularly accessible form; the exhaust gases in particular are not at a sufficiently high temperature to be of much use in generating steam. Heat exchangers are available which can recapture some of this heat, nevertheless, and it seems that usable heat for certain kinds of buildings or for some agricultural scheme might be obtained from this source.

2. Light and electric power

In temperate regions electricity has come to be one of the indispensable features of everyday life. In a land with month after month of short winter days, electric lighting by itself is even more desirable, and the native peoples of the Delta are as aware as anyone of the uses of electricity to run labour-saving devices[1]. Here again, however, economic factors combine to make electricity high-priced and its use a luxury.

Every community in the region covered by this report has electric generating equipment. In Inuvik, there are both diesel generators and a steam turbine; the other settlements have diesel plants. Table IV gives the size of the different power plants as well as the rates for electricity for domestic use.

These power plants provides electricity primarily for government facilities such as schools and for government housing. For native users, the price of electricity is high; even so, electrification is spreading rapidly through the Delta settlements. This can be seen from the following data. In the fall of 1965, 36 Eskimo and 9 Indian families had electricity at Inuvik[2]. At Aklavik there were 12 Indians and 15 Eskimos in a total of 35 to 40 private customers; Ft. McPherson had less than 25 non-government users of electricity, including the Hudson's Bay Company, private traders, and missions. In the summer of 1966 between 30 and 35 houses at Ft. McPherson were wired for electricity; at Aklavik, of a total of about 60 houses (of which Indians live in about one-half and Eskimos in the other) only 9 Indian and 8 Eskimo households did not have power in the spring of 1967.

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1. This is obvious from the requests for electric power made at Tuktoyaktuk in the spring of 1965 (J.D. Flynn, pers. comm.). Here people listed the various appliances they would like to be able to use; the following are the principal items mentioned in the thirty-four applications (not including the universal request for electric lights): washing machine and electric iron (21 times each); radio (18 times); hot plate (14); phonograph (13). Other items listed several times included electric coffee pots and electric fry pans.

2. W.S. Stott, pers. comm.

Table IV

Electrical Generating Capacity and Cost of Residential Service

	Capacity (Kva)	Residential Rate
Aklavik	470	\$0.12/kwh
Arctic Red River	15 (1)	0.12/kwh
Ft. McPherson	750	0.12/kwh
Inuvik	3500	2.22 First 10 kwh (minimum)
		0.0668/kwh 11-75 kwh
		0.05/kwh above 75 kwh
Reindeer Station	40 (2)	0.12/kwh
Tuktoyaktuk	200 (3)	0.12/kwh

(1) To be increased to 40 kva in Financial Year 1967-68.
(2) Two 40 kva generators installed in settlement but cannot be run simultaneously.
(3) To be increased to 300 kva in Financial Year 1967-68.

Sources: Northern Canada Power Commission, Inuvik; Department of Indian Affairs and Northern Development, Inuvik.

Tuktoyaktuk is a somewhat special case, since the primary voltage of the present distribution system is too low to provide much power to people living beyond a small distance from the power house. Even there, however, seven private houses had power at the end of 1966, while a year earlier the Hudson's Bay Company, a private trader, and the Anglican and Roman Catholic missions were the only users of electricity apart from government buildings.

The first point of importance here is that the price of electricity is not so far out of line as it appears. It is, of course, high by city standards: 60 kwh of electricity a month (a figure for lighting and small appliances alone) costs \$5.50 at Inuvik and \$7.20 at Tuktoyaktuk, compared with \$1.59 at Montreal, \$1.67 at Ottawa, \$1.72 at Winnipeg, and \$2.02 at Vancouver (Dominion Bureau of Statistics 1967; these are 1965 prices for the southern cities). Such a comparison is not fair because of the vastly larger and more economical systems possible in a densely populated, highly industrialized area; in the south, these large systems have made the extension of cheap power into rural districts possible. A more valid comparison is with similarly isolated settlements;

an example is the Nantucket Gas and Electric Company, on Nantucket Island, Massachusetts, U.S.A. Here the same 60 kwh per month would cost $6.40 during the winter (Oct. 1 to May 31) and $11.93 in the summer[1]. The situation is similar in northern Alberta. The generating station at Fairview, Alta., has a capacity of 10,200 kilowatts; 60 kwh per month for residential purposes costs $4.30. The plant at Jasper has a total capacity of 4080 kilowatts, and 60 kwh per month would cost $4.70 (Canadian Electrical Association, n.d.; these are 1961 figures). Such information puts the Mackenzie Delta rates in better perspective and shows that they are not unreasonably high for the size of community involved.

Other ways of lighting give another basis of comparison. Here we think at once of gasoline lamps. These turn out to be an uneconomic form of illumination even where electric power costs $0.12 per kwh. At Tuktoyaktuk, for example, a gallon of white gas costs $0.79; this will run a single burner Coleman lantern (Model 200A, approximately equivalent to a hundred watt incandescent light) for 56 hours, or a double-burner one (Model 220F, equivalent to between 100 and 200 watts of incandescent lighting) for 43 hours (Consumer Reports, 29 (1964), 344). At $0.12 per kwh it costs $0.67 to run a one-hundred watt electric light for 56 hours. In addition to the saving in costs, electric lighting is also much less of a fire risk than gasoline lighting.

The fact still remains that electricity is expensive in the Mackenzie Delta, and the problem of providing electricity cheaply is less serious than that of heating houses cheaply only in the respect that heat is a necessity of life in the north, while electricity is but a luxury - although one by which people set great store. As we can expect from the above discussion there seems only slight hope for radically cheapening the cost of power in the short term future.

To understand this better, let us consider the other means currently available for generating electric power. The nearest direct competitor to a diesel generator is a gas turbine generator. It is not economic to build turbine generators as small as diesels - the lower end of the practical range for a commercial turbine generator is three to four thousand kilowatts - so they would not be suitable for the present demands of any settlement in the Mackenzie Delta but Inuvik. Gas turbine units have two main advantages: they have a relatively low capital cost per kilowatt of installed capacity (Cronin and Lokay 1965), and they require

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1. Figures furnished by the Massachusetts Department of Public Utilities, Boston, Mass., U.S.A.

comparatively little maintenance. Set against these are two disadvantages. First, gas turbines have a lower overall efficiency than a diesel generator. At peak load, a 3500 kw gas turbine generator has an efficiency of about 20%, compared to the 30% to 35% of a diesel unit; in this connection, we must remember that the efficiency of a diesel generator is about the same as that of a large steam-powered generating station. This loss in efficiency is counterbalanced to a large extent by the fact that the exhaust gases are at a much higher temperature (about 900°F at full load) so that they can be more easily used in a waste heat boiler. Again taking the example of Inuvik, we might be able to substitute a gas turbine generating system for the diesel generating system and part of the steam generating equipment at approximately the same overall efficiency.

At this point, we run into the second disadvantage: the steam boilers at Inuvik run on a residual oil. Although gas turbines can run on diesel oils or similar distillates, they cannot at present use the heavier residual oil with its corrosive elements. As we have seen, there is a considerable saving in expense in the use of this residual oil; accordingly, it is difficult to see how gas turbine generators could prove very useful in the Mackenzie Delta under present conditions.

Atomic power is another means of generating electricity, and one which seems to sum up in its name much of the wonder of modern technology. Unfortunately in the present application it can be immediately ruled out on the basis of size. In the south, atomic power plants become competitive with other types of thermal generation only when the amount of electricity produced is in the range of hundreds of thousands of kilowatts. The foreseeable market for electric power in the entire Mackenzie Delta is nowhere near this level. The lack of economy of small atomic power plants can be seen in the results of a study prepared with specific reference to Frobisher Bay (Canadian Westinghouse Co. Ltd., 1960; although this study was done several years ago, technological advances made since then seem to help only in the design of much larger reactors). The calculations of this study lead to the conclusion that, under the most favourable circumstances, a five thousand kilowatt atomic plant might compare with a diesel generating plant if oil cost $0.28 per gallon or more; a twenty-five hundred kilowatt atomic plant might be competitive if oil cost $0.48 per gallon. In other words, the market for power in the Mackenzie Delta is too small to make power generation by atomic means economically feasible.

Another way of generating electricity is through the direct conversion of heat to electric power. This has, as yet, been done only on a small scale, and does not seem to hold much promise for supplying the needs of even a small settlement. It might have applications in a single camp; we shall discuss this in the next chapter.

Since alternative means of generating power thermally do not seem to lead to cheaper electricity, on the scale of the demands of the Mackenzie Delta, we have to look elsewhere for means by which it might be possible to reduce its cost. It is obvious that substantial reductions in the cost of power might be possible if some degree of centralization could be produced. Neither the overhead in operating a power plant nor the number of men required to run it increases in direct proportion to the number of kilowatts generated. The extent of this can be seen by estimating[1] the size of operating crew needed for plants of different sizes: for a plant smaller than 250 to 300 kilowatts, three or four men are adequate; above this size, one should have five or six, and more men are needed only when the plant gets above 1000 kilowatts in capacity. In other words, small diesel plants may spend considerably more on salaries and wages than on fuel; this is indeed the case in many of the settlements of the Northwest Territories[2].

Such centralization could be effected by constructing transmission lines between the various settlements. Admittedly, this would be an expensive undertaking. Only crude calculations are possible because of the uncertainties involved, but they indicate that, with present usage and with present rates, furnishing power to Aklavik over a transmission line from Inuvik might be competitive with the present system; were the usage at Aklavik to be doubled, it would probably be so.. The distances between the other settlements are greater, and the situation with them correspondingly less favourable. In addition, there would be a continuing need of a fairly sizable installation at Ft. McPherson to heat the hostel. The possibility is, however, intriguing and deserves further investigation.

A more radical centralization scheme would involve building a hydroelectric plant. Sources of hydroelectric power exist in the area and it should be possible to build a plant of this type to serve the whole region. In addition to the savings obtained by having a single plant, this

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1. E. Humphreys, pers. comm.

2. The following figures are for Financial Year 1963-64: the diesel plant at Ft. Smith (2250 kw capacity) spent $74,813 on salaries and wages against $85,419 on fuel; that at Ft. Simpson (1075 kw) $49,536 on salaries and wages and $25,487 on fuel; and that at Ft. Resolution (325 kw) $22,544 on salaries and wages and $8,519 on fuel (Northern Canada Power Commission, 1964:22).

would mean that the expense of the diesel fuel would be eliminated. At present this is a comparatively small fraction of the total cost of electric power (it contributes about \$0.02/kwh at Inuvik and perhaps \$0.03/kwh at Tuktoyaktuk), but it is a base price which can never be reduced with present methods of generating power, and it would become more important with any reduction in the overall price of electricity.

Although hydroelectric power may well be the long-term solution to the problem of providing cheap electricity in the Mackenzie Delta, the capital investment involved would be very great, particularly in relation to the present comparatively small total electrical load of the region. This expense, of course, occurs in one or another form in every scheme for cheap power, including the current proposal for subsidies. It is therefore well worth-while studying this method, too, in enough detail that a usable comparison can be made between all possibilities.

3. Water supply and sewage disposal

In most of southern Canada, small communities do not need water supply and sewage disposal systems. Individual means - wells and septic tanks - are adequate. In the Mackenzie Delta, as in northern regions in general, the situation is different. In practice, one cannot drill wells for water for household use[1], and even the smallest settlement must depend on surface water, with its problems of contamination, both chemical and physical, and of transport. This is due to the presence of the permafrost layer, which also makes septic tanks with tile fields impracticable. In winter, the disposal of dirty water is difficult; if kitchen wastes and the like are poured outdoors, they accumulate during the winter into grey glacier-like masses of ice, which turn into grey puddles in spring and disperse only slowly. One cannot use conventional piped water supply and sewerage systems, for unheated, uninsulated buried pipes quickly freeze.

Here the crux of the matter is that the community, no matter how little money may be available for such purposes, is faced with providing water supply and sewage disposal services by means which are almost always unconventional and can frequently be very costly. This problem has three parts: obtaining and treating water in sufficient

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1. Wells have been drilled through the permafrost layer to obtain water in fairly large quantities. This has been done in the Tanana Valley in Alaska (George 1966: 422) and in northern Russia (Itskova and Drachnev 1962: 65). The water so obtained is generally quite heavily mineralized and requires treatment before use; as an extreme example, a sample from Noril'sk had 2700 ppm of dissolved minerals.

quantity for the needs of the community, disposing of domestic wastes in a sanitary manner, and providing an economic system to make these facilities available to the inhabitants of a settlement. For clarity, we shall discuss each of these in turn.

a. Water supply. Fortunately, the Mackenzie River is large enough and the population along it sufficiently small that it can form a convenient, unpolluted source of water for the communities of the Delta. The two smallest communities of the region, Arctic Red River and Reindeer Station, use river water directly. At Aklavik the river forms a general source of water in the winter, and ice is stored in ice-houses to provide summer drinking water for government employees. Even at Tuktoyaktuk the harbour is a source of fresh water for the settlement during the winter months. This can be done even though Tuktoyaktuk is on the ocean, for it is close enough to the mouth of the Mackenzie that the harbour water gradually becomes fresh in winter, when the ice cover prevents mixing of the water by wind.

River water has the disadvantage of being turbid at certain times of the year; this is particularly true of the Peel, and, as Henoch (1960: 35) observes, in early summer at Ft. McPherson solids must be allowed to settle out of river water before it can be drunk. Because of this, several of the settlements use lakes as reservoirs. At Inuvik, water is pumped from the river into the lake in winter, when its turbidity is low, and drawn from it in summer, when the river is muddier. A water treatment plant provides microstraining, chlorination, and fluoridation; even so there is a problem with water colour from natural run-off and algae. At Ft. McPherson a lake is used which is flooded every spring; because of its highly coloured water there is a complete water treatment plant.

Aklavik and Tuktoyaktuk also use lakes as a summer source of water[1]. The lake at Aklavik, like that at Ft. McPherson, is flooded by the river at break-up; there is provision for filtration and chlorination. At Tuktoyaktuk the lake water (as also the harbour water used in winter) is chlorinated before use.

In brief, availability of water is no problem at any of the Delta settlements, nor, in general, is treatment to ensure that it is safe for drinking.

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1. Currently, it is planned to install a pumping station and treatment plant at Aklavik which will then allow river water to be used throughout the year.

b. Waste disposal. What might be termed the traditional method in the Mackenzie Delta for the ultimate disposition of human waste is rudimentary: in winter it is put on the ice to be lost during break-up; in the summer it is dumped in the river. This method is still in wide use by the native population of the Delta outside of Inuvik.

All the settlements except Arctic Red River also have more organized methods for the disposal of human waste. The most primitive is at Aklavik, where it is either put in plastic bags and hauled to the garbage dump or simply mixed with garbage. Although the dump floods every year, the currents do not seem strong enough to do more than drop a layer of silt on it.

At Tuktoyaktuk sewage from the government housing is dumped in a natural coastal lagoon, which is cleaned out periodically during heavy storms. At Reindeer Station sewage is hauled to a small lagoon three-quarters of a mile north of the settlement.

Inuvik and Ft. McPherson use the most sophisticated method of disposing of human waste in the region, the sewage lagoon; even these are rather primitive in comparison with those used in southern Canada. In both places, advantage has been taken of a favourable natural situation. At Ft. McPherson a lake is used, which provides a natural outlet for effluent; at Inuvik a roadway was built to form a dike around a depression behind a flood levee, and the effluent currently flows into the East Channel downstream from the townsite.

These lagoons have been quite successful. In the summer, as in the south, treatment of the sewage takes place through the action of aerobic bacteria, algae, and other organisms; in the winter, this is supplemented by a certain amount of action by anaerobic bacteria. It is currently planned to build a similar lagoon for Aklavik, to the northeast of the settlement.

As Yates and Stanley have pointed out (1966: 416), rational design of sewage lagoons for northern settlements is difficult because of a lack of data. Current and proposed studies by the Public Health Engineering Division of the Department of National Health and Welfare should help fill this gap. Apart from this, the lagoons meet the requirements of the settlements. We can say that though current methods of sewage disposal may be unsatisfactory in some of the Delta settlements, technical means are available for sanitary sewage disposal at reasonable cost.

Wash water does not present the same health problem as sewage, but still its disposal is a problem outside the central serviced areas of Inuvik and Ft. McPherson. Aklavik has a system of open drains which are moderately satisfactory in summer. In general, however, waste water is dumped on the ground; in winter, as we have already mentioned, it freezes and accumulates. This problem is a consequence of the difficulty of sewage collection. Though construction of leaching pits would help, it is difficult to see any way of eliminating it entirely except through the introduction of piped sewerage systems.

c. Water distribution and sewage collection. Even though a good supply of water and a means of ultimate disposition of sewage are available, we are left with the problem of delivering the water to the inhabitants of a settlement and of providing for the removal of sewage and wastes. Economically, this is the most difficult part of the overall problem and the one in which it seems most difficult to introduce a southern level of convenience in a form sufficiently cheap to be of wide application.

Two general approaches to this problem are in use in northern Canada, and examples of both occur in the Mackenzie Delta. One is using trucks to supply water and remove sewage; the other, constructing an insulated, heated system which contains both the water supply and sewerage systems.

The piped systems are a much closer approximation to the facilities generally available in the south and, since they are not limited by storage problems, are probably ultimately more satisfactory. They are, however, much harder to justify on economic grounds. As a result, the two such systems in the Mackenzie Delta - the so-called "utilidors" at Inuvik and Ft. McPherson - are limited in extent and serve, in the main, only that part of the settlement which is used for government purposes. Because of this, and because both of these systems are above ground level, they form a highly visible sign of class distinction. A short description will show why they are so expensive and also some of the difficulties they can have.

The system at Inuvik is both more expensive and more complicated. As we have already said, there the water and sewer pipes are kept hot by being put in a box which also contains pipes for supplying hot water to heat the buildings (Fig. 4). Such a system has worked quite well, but this utilidor costs about $200 per linear foot[1]. There naturally have also been certain technical problems. The utilidor had to be built with the heating pipes above the water supply pipes to keep the

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1. W.E. Stott, pers. comm.

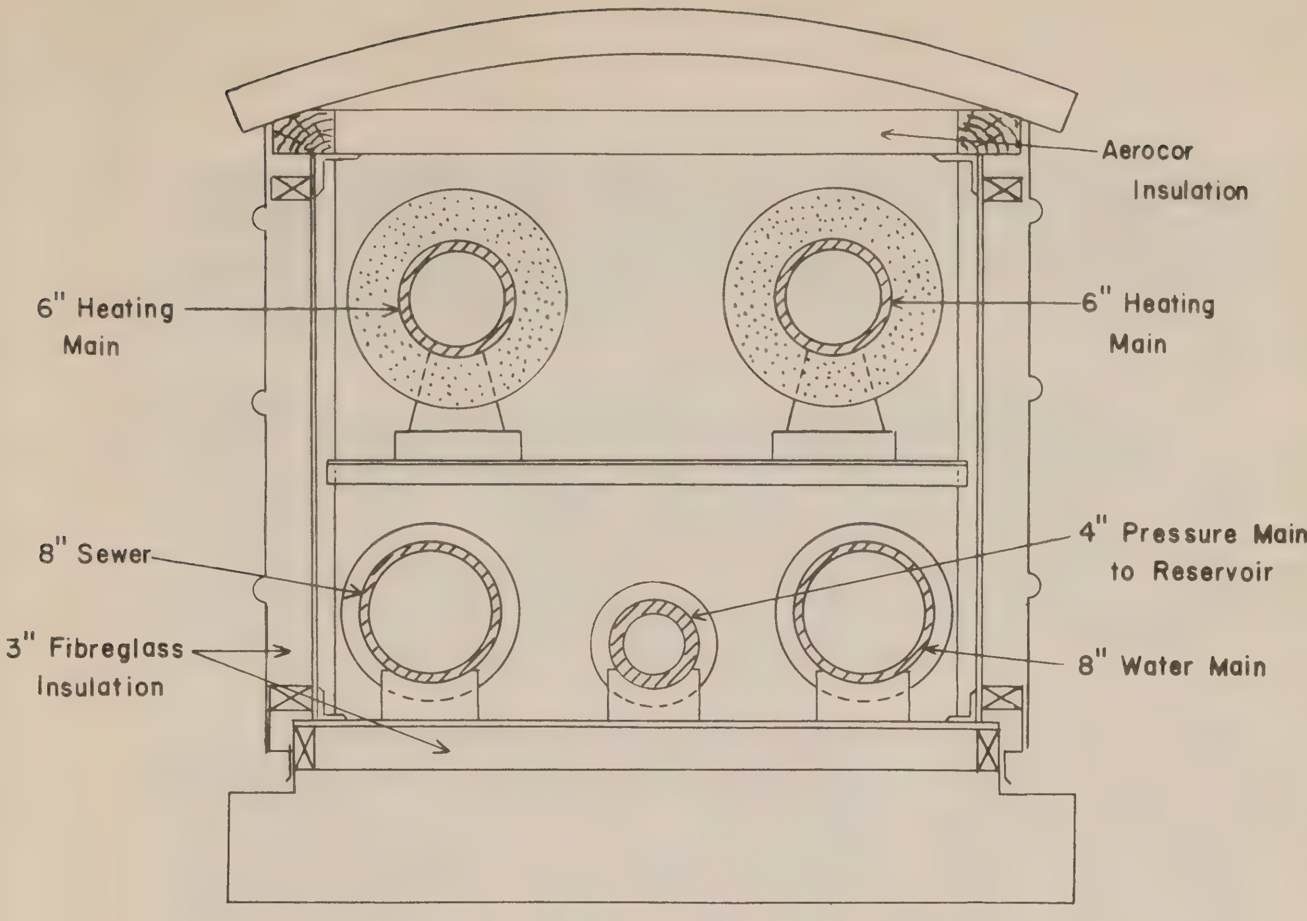
drainage points on the buildings - and, consequently, the height of the piles on which the buildings stand - as low as possible. In winter, this leads to pronounced stratification of the air mass inside the utilidor, with the colder air settling to the bottom. There are also strong convection currents in the air in sloping sections, and attempts to stop these by baffles have not been entirely successful. Both of these lead to the water supply and sewage pipes not receiving as much heat as anticipated, and it was necessary to remove insulation from the heating pipes to keep the water pipes from freezing. In turn, this leads to large heat leakages, and under certain circumstances it seems that a sizeable fraction of the heat produced in the central plant goes solely to heating the utilidor.

On the whole, though, this system has proved quite satisfactory. A particular advantage is that the short sections ("utilidettes") which join the main structure to the individual buildings have their own source of heat and are not liable to freezing. Such freezing is a drawback of the utilidor system at Ft. McPherson. This is a considerably less ambitious and cheaper venture. The utilidor (a typical cross-section is shown in Fig. 5) contains only pipes to supply water and remove sewage. The water supply line runs in a loop, with water circulating continuously; heat can be supplied to it to keep both it and the sewerage system from freezing. The connecting lines to a building do not have their own heat source in this system, so they can freeze if water is not used in the building and there is no flow through them. This in fact happens in severe winter conditions, as in the winter of 1965-66.

Tuktoyaktuk is a good example of the other method of supplying water and removing sewage, through the use of trucks. There government housing and the Hudson's Bay Company buildings have individual pressure systems: each house has a water storage tank, holding between 180 and 500 gallons and filled twice a week, and a pressure pump to provide water at 20 to 30 psi pressure. There is a 500-gallon waste tank in each system. This arrangement does not extend to non-government housing. To supply water to the rest of the settlement, there are four water tanks, each holding approximately 500 gallons and with heating for winter. A contractor hauls garbage; beyond this there are no general arrangements for sewage collection and disposal.

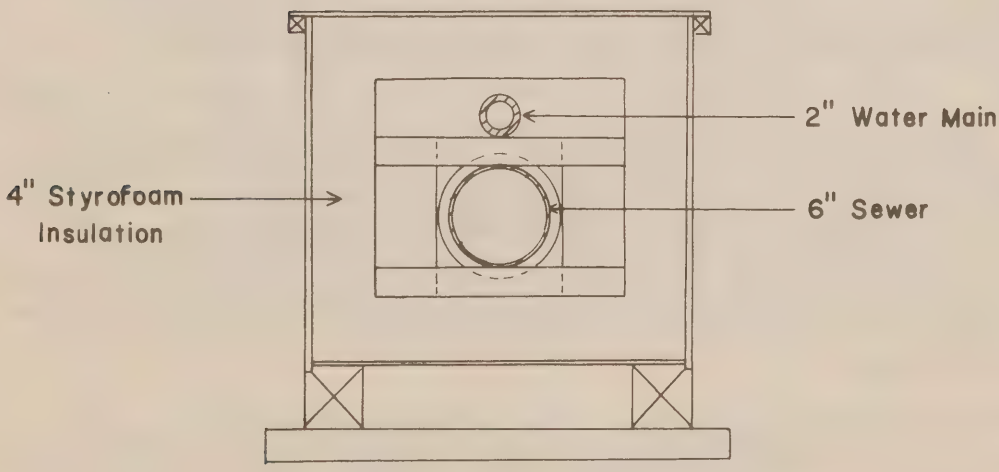
This system provides at least a minimum of convenience for the native population of the settlement at a reasonable cost. With the addition of specific provision for hauling away human waste when

Fig. 4



Cross-section View of Inuvik Utilidor

Fig. 5



Cross-section View of Ft. McPherson Utilidor

put in plastic garbage bags, it closely parallels the present Department of Indian Affairs policy for the small northern settlements (Northwest Territories Council, 1966: Vol. II, 581). As the following brief description shows, it is followed more or less closely by current practice in the unserviced areas of Inuvik and Ft. McPherson and at Aklavik.

At Ft. McPherson water is presently available only from the utilidor system or at the Northern Canada Power Commission powerhouse, but two 2500-gallon water supply tanks are going to be installed. Sewage is put in plastic bags as described above. The unserviced part of Inuvik also has water storage tanks; there the provision of central points for the pick-up of waste from chemical toilets was tried, but was not a success. Now a box has been put outside each house to hold plastic bags. At Aklavik there was until 1966 only a summer water supply system: a run of 3 in. pipe, laid on the surface of the ground, with taps at frequent intervals. This was fed, through a pressure tank, from the lake mentioned above. This system was of no use in the winter; furthermore, even though it was drained as carefully as possible in the fall, it tended to hold water with resulting trouble from cracking. Currently heated water tanks have been installed in Aklavik too, and the piping system is being refurbished for summer use in filling them. In the winter they will be filled by truck.

This description shows both sides of the question of water supply and sewage disposal. On the one hand, an economic facility brings little more than the bare minimum of convenience to those living in the settlements (and often not even this); on the other, piped systems for supplying water and removing sewage are currently so expensive as to be available to only a very small fraction of the inhabitants of any settlement.

Let us consider this last point first. Although a large part of the design of any utilidor system - and, correspondingly, to a great extent, the cost is determined by local conditions such as the terrain on which the settlement lies (if gravity flow sewers are to be used) or available sources of heating, it is still of value to contrast the various types of design that have been tried and to see what might be of use in the Mackenzie Delta.

The general practice in climates like that of the Mackenzie Delta has been to put both water supply and sewerage systems in a single container, usually insulated, and to supply heat, either to both lines, or to the water line alone; in this latter case, enough heat must be transferred from one pipe to the other to keep it from freezing. Various

sources of external heat have been used: at Inuvik, as we have seen, it is provided by the pipes carrying the building heating water; at Norman Wells[1] heat is similarly provided by a steam line. Elsewhere pipes are heated electrically.[2]

Another approach is to heat the water at the input to the system. At Vorkuta and Noril'sk in the U.S.S.R. this is done by using the cooling water from the power plants for the city water supply (Itskova and Drachnov 1962: 68). In this case, the water must flow continuously to keep the entire system above freezing. One way of ensuring this is to bleed the system, as is done at Dawson (Lotz 1965:43), and at Tiksi in the U.S.S.R. (Itskova and Drachnov 1962:68). Such a practice uses a considerable amount of water; at Tiksi half of the settlement's water is wasted through the drains.

An alternate system is to use a recirculating water line and add heat in the supply plant as required, as is done at Ft. McPherson. An interesting extension of this scheme is to have a recirculating system both in the water supply and sewerage systems, as has been recently installed at Frobisher Bay (Yates and Stanley 1966:417, and pers. communication). There each of the houses served have sewage settling tanks, which have to be cleaned periodically; the effluent from these is pumped into the sewage line. The advantages of such a system are considerable: there is no need to worry about adequate heat transfer to the sewage line; more important in many cases, the need to design the sewerage system to allow gravity flow is removed. The detailed behaviour of this system will have great influence on the design of future water and sewerage systems in the Canadian north.

Apart from this, there are several directions of study which might have immediate consequence for the Mackenzie Delta. One is the search for technical improvements in utilidors as they are presently conceived. Here a number of small questions arises, whose solution might give considerable economies in the construction and operation of conventional utilidors. One example is the problem of ensuring that in systems where the sewer line does not have its own source of heat, it receives enough heat that it does not freeze. A solution

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1. Cf., for example, Drawing D.C. 5112, of the Department of Transport, Air Services, Construction Branch, Edmonton Region.

2. E.g. at the Dept. of Transport installation at Coppermine, N.W.T.

might be the use of thermal connectors - metal straps - between pipes, though such a scheme would not work with the transite pipes used at Inuvik. Another problem is the prevention of stratification of the air in the utilidor, as happens at Inuvik. An answer to this is to fill sections of the utilidor completely with insulation, as was done with the utilidor extension at Norman Wells, though the results of this from the point of view of heat transfer are not entirely clear. A second problem is the search for cheaper insulating materials; insulating with moss has been suggested and is used in more southerly environments (Grainge 1965), and, several years ago, was proposed, in combination with electric heating of the sewer, for Tuktoyaktuk (Copp 1960). The practical value of such a scheme in the conditions of the Delta does not seem to have been experimentally tested.

A more radical departure would be investigating the practicability of burying insulated pipes in soil conditions like those of the Mackenzie Delta. There are several reasons against such a system: if the ground around the pipe thawed, it would lose its bearing strength; furthermore, the insulation might become water-logged and lose its insulating qualities. Combining these serious design questions with ease of getting at above-ground systems for extension and repair, we have ample justification for current practice; and, in fact, the Russians seem to have reached the same conclusions[1].

On the other hand, apart from the aesthetic advantages of an underground system and its convenience when it is necessary to extend roads, it should profit considerably from being less subject to damage and from the insulating qualities of the ground. In principle it is possible to design a system in which heat loss to the surrounding earth is at such a low rate that it would not disturb the permafrost conditions; in practice, too little is known about the rate at which the pipes would lose heat. Here, as with the technical points raised earlier, experiment seems to provide the only satisfactory answer. Again, studies are underway in Inuvik by the Public Health Engineering Division of the Department of National Health and Welfare. These will provide some information both on heat loss from buried pipes and on the behaviour of various types of insulation. Such studies may show lines along which a considerably cheaper type of utilidor system can be designed.

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1. Soviet Union Today, October 1965:1.

Piped distribution of water and removal of sewage seems the only solution that can equal southern facilities. Its drawbacks are expense, as in the present systems, and the fact that any new reliable and cheap system will require not only careful design but also careful testing to ensure its practicability. This may require a considerable amount of time. Because of this, trucking water seems the only sensible measure for the present. To be sure, getting water from a storage tank, no matter how close, and disposing of sewage by putting it in a plastic bag are far from approaching any reasonable level of convenience, but with water trucks the individual can have water delivered to his house and this, combined with an individual pressure system and storage tank, can provide a reasonable alternative to a utilidor.

This arrangement has the disadvantage that if a large number of houses were to invest in such storage systems, the total expense of converting them to use a utilidor might become large and, accordingly, there might be little enthusiasm for changing to the better arrangement. For this reason, an especially interesting line of study would be systems which would allow such a conversion at the minimum expense. The Frobisher utilidor described above might be one step in this direction; another might be a system such as that in use at Coppermine, where the supply and discharge lines - in other words, the utilidor - are heated only from time to time to allow storage tanks in the individual buildings to be filled and emptied.

4. Housing

Much of the Indian and Eskimo population of the Mackenzie Delta lives in housing that is cramped and, more often than not, of mediocre construction.

We have already seen one of the reasons for small houses in the high costs of heating. On the basis of a single house, balancing size against over-crowding is a problem requiring great ingenuity in design but is only indirectly one relating to technology, at least at the level of the present study.

Modern technical studies have, of course, influenced northern building construction through the overall design of buildings to conserve as much heat as possible. The most direct approach to this is to combine individual dwellings into apartment houses. By so doing the proportion of outside walls in each unit so is reduced, and, consequently, the amount of heat lost to the environment. In general the use of a more efficient heating unit is then also possible.

Though such designs are quite acceptable for government housing, we may question how useful they would be for individual, presumably privately-owned, houses in small arctic settlements. Studies aimed towards arranging buildings in compact groups to take the best advantage of winter sunlight and to afford the most protection in storms seem of more practical value. A great deal of work along these lines has been done in the U.S.S.R.[1] This, however, belongs more to the field of town planning than to technology and again goes beyond the scope of the present report.

We are left with direct contributions of technological research to problems of arctic construction, such as the study of satisfactory methods of construction on permafrost and a demonstration of the advantages of prefabrication. Although the latter may be of doubtful value in a region where labour is readily available, the importance of knowing how to construct buildings on permafrost cannot be gainsaid.

In broad terms, the technical problems of construction in a region like the Mackenzie Delta are known and can be dealt with. We have already mentioned that as long as the soil there remains frozen, it has ample bearing strength; problems arise only when it thaws. The solution is to keep the ground as nearly as possible in its natural state and to avoid letting extraneous heat, as from a building, enter it. In short, the problem reduces to that of inserting an insulating layer between the building and the ground.

Two ways of doing this are in common use. The more elegant is to support the building on piles and leave a free air-space under it, thus generally diminishing the amount of heat transferred to the ground. If the piles are set in the ground and then allowed to "freeze in", they develop ample bearing strength. This method has been widely used in construction at Inuvik and is the only satisfactory one for large buildings. It has provided almost complete success: there has been only the smallest amount of difficulty with piles shifting[2] and none with buildings settling.

The second method is far cheaper. It is to put a layer of insulating material - typically a gravel pad - on top of the natural soil

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1. See, for example, Problemy Severa 10 (1964): 60-131, of which an English summary appears in Polar Record 12 (1965): 603.

2. The few piles that have shifted seem either to have been in places where water could accumulate or in positions where they bore abnormally light loads, as in the utilidor system (Northern Canada Power Commission 1964: p. 8).

cover and use it as a foundation. This is entirely adequate for small houses; its main disadvantage is that the gravel pad tends to erode away unless it is taken care of. In spite of this last, in our context of providing cheap equivalents to southern conveniences in the Mackenzie Delta, we can consider the provision of suitable building foundations for small houses as a problem that has been solved satisfactorily.

Technological study has also led to the production of prefabricated buildings for arctic use. In these attention has been paid to providing as good insulation in the walls and as much overall tightness as possible; in addition, the benefits of mass production can be turned to making a good quality product at the lowest possible cost. Such housing is extremely useful in the central and eastern parts of arctic Canada, where building materials are hard to procure. Prefabricated buildings can be brought by boat - or, if necessary, by air - assembled, and put to use with a minimum of labour.

Though the situation is different in the Mackenzie Delta, prefabricated houses brought in from the south are generally preferred there too. Presumably the reason for this is that the building is sure to be well made and tight; in other words, the purchaser is depending on the technical knowledge and experience available in southern construction companies. Unfortunately this type of technology is not aimed at contributing in a broad way to the economy of the native inhabitants of the Mackenzie Delta.

This preference arises from the lack of a suitable local competitor; in turn, the absence of competition seems to be due to two factors. One is the need for continuing encouragement of local construction of good quality; this is a problem of administrative decision and encouragement and of education, and is beyond the scope of this report. The other is the need to make the greatest use possible of local materials and labour, and it is here that technology may be of help.

For example, take the wood available in the region. Timber is available in large enough quantities for the needs of the region, and a saw-mill has been operating, first at Aklavik, later at Arctic Red River, for several years. The wood from this mill has been put to

use in low-cost housing, and it could be used in wood-plastic combinations as a substitute for higher grade lumber brought from the south (Platts 1964: 15). Though these last might be more expensive than raw lumber, even at Inuvik prices, they could widen the economic base of the region.

Technology might also be useful in cheapening local construction through providing better insulation. The question has been raised, from time to time, of using low density plastic polymers, such as foamed polystyrene or polyurethane, for insulation (Sater 1963: 271). Of these, the polyurethanes seem the most promising; in the first place, they can be foamed in place, a method which would avoid the extra shipping charges for bulky materials; furthermore, a certain amount of work has been done on forming these foams with inert gases, which improves their insulating qualities by a factor of two in comparison with conventional materials which contain air (Platts 1964: 11). Another use of plastics in providing better building insulation might be in the formation of translucent blocks to admit light rather than windows, which are often serious sources of heat loss (Platts 1964: 4).

In general, there are sufficient raw materials and technical practices available to make good quality, low-cost housing construction feasible within the Mackenzie Delta, and ways of encouraging this might well be studied in more detail than they have been up to now. A large part of the problem, however, lies not so much in the development of new techniques as in the continuing encouragement and supervision necessary to produce the best quality possible with the means at hand.

5. Transport

The effects of the isolation and arctic location of the Mackenzie Delta have already been seen in the problems of heating and of providing electricity. Short summers and the great distance to centres of production combine again to make transport another very serious problem.

It is also a difficult subject to discuss in that it covers such a wide range. For clarity, we shall discuss transport here in three parts, arranged by the distances involved: transport within a single settlement; transport within the Mackenzie Delta as a whole; and transport to and from the more heavily populated regions of Canada.

a. Transport within a settlement. The ability to bring heavy materials and equipment to every house in a town is so fundamental that we almost always take it for granted. Without it, we could preserve few of the benefits of communal living - if examples are necessary, there are the need of getting fire equipment quickly to a fire and the need of easy

access to buildings to maintain their services. Roads are the standard answer to this, and each of the settlements of the Delta (except Reindeer Station, which is essentially a row of buildings along the river) has its own road system, though of different degrees of usefulness.

Through its position as administrative centre, Inuvik has the best developed and most satisfactory road system; they are built of gravel and kept in good repair.

The road systems at Ft. McPherson and at Tuktoyaktuk can also be considered quite satisfactory for the needs of the settlements. That at Ft. McPherson has been built according to a town plan laid out in 1948 (Henoch 1961: 93). As we have mentioned earlier, the nearest gravel to Ft. McPherson is at Pt. Separation; this is too expensive for practical use in road building, and the roads there are surfaced with soft shale dug from a pit near the town. As Henoch (1961: 90) comments, "fortunately there are only a few vehicles in Fort McPherson".

At Tuktoyaktuk there is a certain amount of sand and gravel available for road building, though the total extent of the deposits seems limited. The main road there is that connecting the settlement with the airstrip and the DEW Line station, which, fortuitously, runs past - or near - about half the houses of the settlement. In the past two years this has been supplemented by other roads which now go to almost all of the houses in the settlement.

Aklavik's roads are notorious. Again, there is a fairly satisfactory street plan. The roads, however, are only tracks in the silt; they are all right when the ground is frozen in winter or during dry periods in the summer, but, during spring or after any rain at all in summer, they are extremely muddy and virtually useless. They also require a disproportionately large amount of work. About their best feature is the fact that they do give access to almost every building.

Considering the limited extent of the Mackenzie Delta settlements, it should be possible for all of them to have completely adequate all-weather road networks. Where sand and gravel are available, the technical problems can be solved quite easily; apart from the experience gained at Inuvik, the techniques of building roads on muskeg and permafrost have been studied in detail in construction projects

farther south (Wallace 1961: 155). In the case of Aklavik and Ft. McPherson, the gravel deposits are so far away and of such a nature that it is doubtful that they can continue to provide large quantities of material on an economic basis. Because of this, other possibilities - as an example, the use of bonding agents to make a subgrade directly on the permafrost layer - should be investigated. In general, a study of the relative costs of building roads of different types in the various settlements would be both useful and interesting.

b. Transport within the Delta. Individual towns may have adequate road systems, but the situation changes abruptly as soon as we go beyond their limits. The only roads of any extent are still purely local: the one we have already mentioned between Tuktoyaktuk and the DEW Line site and those connecting Inuvik with its airport and with the naval station - perhaps twenty-five miles in all. There are no all weather roads between the settlements and only a few recognized overland trails, such as the one between Ft. McPherson and Arctic Red River or that between Tuktoyaktuk and a fishing site on the Eskimo Lakes. From time to time, "winter roads" have been built; examples are the road from Aklavik to the gravel deposits twenty-five miles inland and the oil companies' roads around Ft. McPherson and Arctic Red River. Most of these are probably short-term undertakings, but they show the particular problems of building and maintaining this type of road in the region.

To a certain extent the river channels counteract the lack of a road network. Boats use them in the summer; in the winter they can make good trails. They have two disadvantages. First, for about two months of the year - one in fall, one in spring - the ice is too thin or too soft for safe travel with present-day vehicles. Second, even in the middle of winter many of the channels are not safe because of water on the ice, and extended detours may be necessary.

Land transport is supplemented by light aircraft, which have greatly reduced the isolation of the settlements, particularly during break-up and freeze-up. Inuvik and Tuktoyaktuk have year-round airstrips; Aklavik also has a strip which is used during the winter and spring. Communication between these three settlements is possible by air throughout the year. Ft. McPherson and Arctic Red River are still isolated to a certain extent in fall and spring, when landings can neither be made on the ice on skis nor on the water on floats. The former, however, can generally be reached all fall by using the sand bar which stretches in front of the settlement.

In describing the use made of these transport networks, it is convenient to separate travel from one settlement to another from that based on one of the settlements (or on a camp) and carried out while hunting, fishing, or trapping.

Travel from one settlement to another is primarily by air. People travel between settlements by air almost without exception, and a considerable amount of freight is also carried by air from Inuvik to the other settlements. This mode of travel, as mentioned earlier, centres on Inuvik. A scheduled air service connects Inuvik with all the other settlements (except Reindeer Station) between two and four times a week; this is supplemented by a considerable number of charter flights.

Surface movement of freight within the Delta is quite limited. In the summer a certain amount of lumber and other materials are carried around the Delta by barge. The main pattern of barge transport, however, connects the Delta settlements more or less individually with the south - this has been likened to a string of box cars being brought down the Mackenzie and being dropped off, each at its proper destination. This practice is due to the expenses of trans-shipment: it is cheaper for the barges to go to the individual settlements than it would be to unload them all in, say, Inuvik, and then distribute goods around the Delta from there.

In the winter, a small amount of goods is hauled by Bombardier "Snowmobile". In the winter of 1966-67, gravel was hauled over the ice from the Richardson Mountains to Aklavik; in the winters of both 1965-66 and 1966-67 attempts have been made to haul freight from Inuvik to Tuktoyaktuk. Such trucking, if done with modern equipment, seems to be successful, but, of course, it requires keeping a road plowed open.

Apart from these, surface travel within the Delta falls mainly into our second class: travelling from a settlement while hunting or trapping or when going to a camp. We must accordingly turn to this to see much of the influence of technology on the transport practices of the region.

Traditionally, the native inhabitants' occupations - fishing, hunting muskrat, and so on - were carried out with the help of a canoe

in summer and a dog team in winter. Technology has changed both of these. The adoption of mechanical propulsion for boats came earlier and is now almost universal. Outboard motors are standard for the canoes and small boats that are common in the Delta. A few larger boats with inboard motors are also found, primarily at Tuktoyaktuk, and are used in whaling.

More recently, individual means of transport have been developed to give mechanical competition to the dog team. The most widely used forms of these are a motorized toboggan and an oversnow vehicle roughly equivalent in capacity to a one ton pick-up truck.

The motorized toboggan - as often as not a Bombardier "Ski-doo", the name by which all such vehicles are commonly called in the region - is quite closely equivalent to a dog team; it can carry one, or possibly two, passengers, and can tow loads of up to 500 pounds on a well-packed trail. Propulsion is furnished by an endless belt driven by a one-cylinder motor. These vehicles are quite popular in the Mackenzie Delta, particularly along the coast: in the winter of 1965-66 there were about as many "Ski-doos" at Tuktoyaktuk as dog teams (roughly two dozen of each). Farther inland they seem less popular (in early 1966, there were only nine at Aklavik, compared to about 65 dog teams; in early 1967, only two Indians at Ft. McPherson had such vehicles), but whether this reflects greater faith in the reliability of dogs or the fact that "Ski-doos" are less suitable for forest travel is not clear.

The larger vehicle, a Bombardier "Snowmobile "(invariably called a "Bombardier") is fully enclosed. Due to their size and high cost (about $6000 landed new, compared to $850 for a "Ski-doo"), most such vehicles in the Delta belong to the government, to the missions, or to organizations such as the Reindeer Project. There are only two privately owned ones at Aklavik and three at Tuktoyaktuk.

Both these vehicles are far from ideal. The "Ski-doo" is primarily made for sportsmen in the south and is not a heavy-duty vehicle. To be reliable, a "Bombardier" requires a great deal of maintenance, which is frequently just not available in the region. They are expensive to run - under favourable operating conditions, a "Bombardier" can be expected to go 4 to 5 miles on a gallon of gas. For their price, however, they are the best - or only - things available, and they are used for this reason.

The problems the Mackenzie Delta faces in the field of transport are clear. Aircraft are the only means of transport that approximate giving year-round service; this flexibility is accompanied by a fairly heavy expense. Surface transport is simply not available for at least two months every year; it is still less attractive because one form of transport - oversnow vehicles - must be used in the winter, another - boats - in the summer. Finally, if we except attempts to truck freight over the ice, available mechanical forms of winter transport are expensive and tend to be unreliable; dog teams may offer reliability, but at the cost of a large amount of time spent, throughout the year, in catching fish for their food.

The first step in providing an alternative to aircraft may well be to concentrate on the winter months alone, say from November until early May. Then winter roads could be used. These - whether for tractor trains or for trucks - are quite a conventional form of transport both in northern Canada and in northern Russia (Korsak 1963). As we have mentioned, such roads have been successfully used by oil companies in the region surrounding the Mackenzie Delta, and a scheme of winter roads linking the various settlements of the Delta has been proposed.[1]

In this situation the technical problems are, by and large, known, though apparently overland parts of a winter road in the Mackenzie Delta are rougher than in corresponding terrain farther south, presumably because the light dry snow of the area does not pack as well. The difficulties are purely economic. If river channels were used for such roads in the Delta, the routes between the settlements would be considerably longer than the straight-line distance on aircraft can fly, with a corresponding reduction in the financial advantages of surface travel. Further, winter roads lead in general to expensive freighting; figures of $0.10 to $0.60 per ton-mile are common for trucking freight over them, and the lower rates can be attained only if considerable effort is spent on laying out the roads and in maintaining them so that trucks can travel at speeds of up to 30 to 40 mph (Hemstock 1965: 2).

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1. Fr. J. Adam, o.m.i., Inuvik, pers. comm.

Such arguments tend to generalize, and a useful counter-active may be to cite the use of a over-ice road to bring gravel to Aklavik by truck in the winter of 1966-67. It is estimated that this gravel, brought 25 miles by road, cost about $7.00 per cubic yard delivered;[1] gravel brought to Ft. McPherson by barge from Pt. Separation (about 30 miles away) costs $13.50 per cubic yard delivered. Here delivery by truck is simpler and cheaper because of the smaller amount of handling involved and using a winter road was very sensible.

In general, though, there is the question of whether the use of such roads between the settlements would justify their construction and maintenance. It is risky to try to predict what freight will move over any road once it is built; furthermore, the pattern of supplying freight to the Delta may well change radically in the future, as would almost certainly happen if a road were built to Ft. McPherson from the south. Nevertheless, a rough economic study of the costs of such a network of winter roads and of their projected present and future use would be of great value.

For year-around surface transport, the most promising development towards a practical vehicle is the air-cushion vehicle. Such vehicles, with their extremely low bearing pressure, can be driven indifferently over ice, water, and low-lying terrain; they have enough ground clearance to surmount pressure ridges such as are found in Kugmallit Bay. Trials of one were successfully held at Tuktoyaktuk in the spring of 1966 and are discussed elsewhere (Cooper and Storr 1967). As presently built, such craft suffer from various technical problems in cold weather operation. In addition, the vehicle used in the Mackenzie Delta trials (a British Hovercraft Corporation SR.N5) had a cargo capacity of about 3000 lb (under overload conditions, 5000 lb) and used fuel at an average rate of 1.58 gal/mi. Though these vehicles are more efficient cargo carriers in larger sizes, this suffices to show how much further developmental work is necessary before such craft can see general commercial use in the Mackenzie Delta. Their performance seems sufficiently promising, however, that further work with them should be well worth-while.

The problem of carrying freight economically on a year-round basis may be difficult, but that of cheap transport for individuals

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1. S.W. Hancock, pers. comm.

is even more so. Over-snow vehicles have been extensively studied, particularly from the point of view of military applications (Mellor 1963), and the basic principles of their design are well known. There are a great number of military over-snow vehicles, which possess the reliability which is so often lacking in those in current civilian use. The majority of these vehicles, however, are not available commercially; when they are, they are so high priced that few could afford them. In its price range, the Bombardier "Snowmobile" is a good vehicle, but it cannot be subjected to too much abuse. Here the best hope for the future lies in the present popularity of motorized toboggans in southern Canada leading to increased reliability and a more useful product overall for northern use. The fact that in the south such vehicles are generally bought for short-term sporting use does little to encourage this hope.

This discussion of transport within the Delta can be summarized as follows. At present, the most satisfactory means of travel or of sending freight is by aircraft; boats supplement this during the summer, and various fairly unsatisfactory means of surface transport during the winter. In the field of public transport and freighting, winter roads seem to offer the best short-term prospects; air-cushion vehicles and the like may well be the long-term answer to the need for year-round surface transport, but they will require some development even before they can be considered a useful vehicle and more before they become economic. The availability of better individual transport for the winter months and better freighting facilities in general is limited not so much by the need for further technological research as by the small demand produced by present overall conditions in the region.

c. Transport linking the Mackenzie Delta with the South. Here there is a comparatively economic means of moving freight in bulk: barges on the Mackenzie River. Still, since the shipping season is short (mid-June to mid-September), freight rates are not as low as one commonly finds with water carriage. They run about $0.03 per ton-mile, with products requiring special handling being more expensive; for example, it costs $0.79 per hundredweight to ship oil from Norman Wells to Inuvik, or nearly $0.04 per ton-mile. This relative expense arises from two factors: the barges and other equipment must lie idle the greater part of the year, and there is considerably less freight moving from north to south than from south to north. It would be difficult to overcome these.

Barge service is supplemented by air freight, which has been steadily increasing from year to year. At present there are four scheduled commercial flights a week between Edmonton and Inuvik, occasional all-cargo flights, and occasional service from the Yukon. Contrary to what might be expected, air shipments seem to supplement those by water rather than replace them. The division is roughly that barges bring oil, heavy materials, and bulk food; air cargo consists of perishable items and materials needed quickly, and therefore does not change much in nature from season to season. Again contrary to expectation, the peak period for air freight is in the summer; this is presumably due to field work by commercial companies like the oil companies.

Thus we have a basically cheap form of transport - barges - which have to lie idle much of the year, supplemented by the much more expensive, but year-round, service given by aircraft. All shipping expenses are further increased by the low volume of traffic from north to south, so much so that northbound freight has, in practice, to pay for almost the entire round trip.

Current technological developments might reduce the cost of transporting particular items. Oil is an example; there is a device - the Dracone - which is constructed specifically to carry liquids that float on water. It is a large sausage-like nylon container, which can be filled, say, with fuel oil and then towed behind a tug. When empty, it can be folded up and returned as deck cargo; this would be a considerable advantage on the Mackenzie River. The use of such devices, however, offers considerable technical problems. First, they would have to be emptied completely at their destination; since a small Dracone is 101' 9'' long and 5' in diameter, with a capacity of 11,300 gallons and an empty weight of 2240 pounds, this would require a fair amount of equipment. Other obvious problems might arise in towing the Dracone down-river at low water, through rapids, or through loose ice.

The general problem, again, is that of furnishing year-round transport that is also cheap. The air-cushion vehicle, as discussed above, is one candidate for doing this, though it seems at present that economic freighting can only be done by very large craft. Another means that has repeatedly been suggested is the airship; one of the latest proposals of using such craft has come from Russia (Alekseyeva 1965). They are suggested as having particular promise for carrying

building materials to isolated places and in various applications in forestry. Operating costs are estimated as roughly one third those of airplanes and three times those of road transport; this last does not take the cost of building and maintaining the roads into account.

Airships have, of course, been used several times in the arctic; the most recent flight of one in northern Canada was a trip to Resolute and Ice Island T3 in 1958 (Greenaway 1959). There is no question that they could be used to carry freight to the Mackenzie Delta, but airships have several features which cast doubt on the economic practicability of such a venture. One is the need to fly at low altitude on long flights; this introduces problems of icing in cold weather and - under overland conditions such as prevail in any route to the Mackenzie Delta - of increased daytime air temperatures and loss of buoyancy in warm weather. Second, airships cruise at lower speeds than aircraft (in 1958 cruising speeds were between 40 and 43 kt.) and are therefore more affected by winds. In addition, preparing a suitable landing strip and mooring pole requires a fair degree of care, and large ground handling crews are necessary; in 1958 crews of 37 men were used both at Churchill and at Resolute. All things considered, the advantages to be gained by the use of airships seem very small.

At the present, trucks seem the logical competitor to airplanes for year-round freighting. Indeed, though the costs of trucking are higher than those of shipping by barge, the convenience gained goes far towards overcoming this difference, as experience at Yellowknife has shown (Bourne 1963: 102 ff.). As a long term project, an all-weather road to the Mackenzie Delta seems the most practical solution to many of the problems of transport; winter roads could form a highly satisfactory supplement to present means of freighting. The potentialities of such roads should certainly be fully investigated; but, as we have said above, these involve economic and engineering problems rather than ones requiring technological development, and so fall outside the province of the present study.

We may conclude this discussion of the means of transport by stating the main points that have been made.

Continuing study is necessary on the economics of roads at all levels. Within the settlements, the costs of providing satisfactory all-weather roads should be considered carefully. At present, winter roads seem the best answer for supplementing barge and aircraft service, both within the Delta and for linking the Delta with the south; the existence of any technical problems arising in building good quality winter roads in the particular conditions of the region should be investigated. On the

whole, these problems seem to be well known; further technological research could, however, help in the question of providing suitable streets for a settlement like Aklavik, which is built on silt and fine sand and does not have a convenient local supply of sand and gravel.

In addition, there is a real need for a vehicle which could provide reliable, year-round surface transport between any two points in the Mackenzie Delta. The air-cushion vehicle holds the most promise in this, but as presently built it is too expensive and not rugged enough for common use in these regions. Its most obvious use would be in freighting, and there remains a need for a commercially built, reliable, cheap form of oversnow transport for individual use in the winter.

6. Communications

The entire field of communications has been studied intensively during the present century. Isolated regions, in particular, have benefitted, and the Mackenzie Delta is no exception. In general, the region has facilities quite comparable with those available in the south.

One example of these is the telephone service in the Delta. Each settlement (except Arctic Red River, which is tied into Ft. McPherson) has its own automatic dial telephone system. The settlements are connected with each other through an automatically controlled radio system centred at Inuvik. This system suffers from minor interruptions, but works very well on the whole.

Inuvik, in turn, is linked to southern Canada by a telephone line. The capacity of this line - one pair of cables - is a good example of what modern communications technology can provide. The entire system carries up to sixteen separate channels: from Inuvik there are three toll circuits to Yellowknife and southern points in general, two to Norman Wells and one to Ft. Good Hope; there are two program circuits to carry CBC radio programs, one circuit for air traffic control, and a voice frequency carrier telegraph circuit which, in itself, can carry fifteen teletype circuits. This "land line" has helped considerably to remove

the isolation of a region in which, in the past, the only rapid means of communication with the south was by radio.[1]

The radio is another very familiar way in which modern communications enter into everyday life. The Mackenzie Delta has its own radio station, CHAK, at Inuvik, and almost every family has a radio. In addition to types of programs familiar in the south, CHAK broadcasts messages to people in the region three times a day; to a certain extent, this makes up for the lack of a more widespread telephone service.

Apart from these, there is still considerable use, principally among government services, of two-way radio telephony. The RCMP detachments are the principal example, but the Reindeer Project and the Canadian Wildlife Service field camps also depend on it. As is well known, radio telephony in the arctic is particularly subject to fading and blackouts; the services in the Mackenzie Delta, being in the medium frequency range, are no exception. On the whole, though, they are adequate for the degree of reliability required.

The level of communications technology within the Mackenzie Delta seems satisfactory for present practical needs. The exception to this is a provision of emergency means of communication, to which we shall return in the next chapter. Beyond this, there is the prospect of a local, small-scale television station, relying on taped programs, and, somewhat further in the future, that of relaying programs from the south by satellites. Both of these are of great importance, not only because of their value as entertainment and in reducing the isolation of the region, but also in their educational possibilities. They seem, however, to have little immediate bearing on the level of living of the native population of the Delta, and therefore lie beyond our present interests.

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1. In any discussion of this "land line" the question is raised of why an "old-fashioned" system of wires was installed rather than microwave repeaters, which could then carry television. It may be observed that microwave systems are designed for bulk transmission; a single system can carry six channels, each with a capacity of six hundred voice channels - or over two hundred times the capacity of the system presently in use, which seems quite generous for the foreseeable needs of the region. A small microwave system, one designed for the needs of the area, with say sixty channels, would not carry television, which needs some six hundred channels. Apart from questions of over-design, there is also that of cost: a microwave system would cost at least ten to twenty times what a land line does.

7. Food

The Mackenzie Delta is too far north for dependable farming; almost all food, except local meats like reindeer meat and fish, has to be brought from the south. As a result, the variety of fresh vegetables available in the stores is meagre, especially outside Inuvik, and prices are high. Meat is frozen and expensive - except for reindeer meat, which can be bought at $0.42 per pound wholesale (or $0.69 per pound cut and wrapped).

This situation, of course, is basically an economic one. To be sure, vegetables can and have been grown, on a small scale, at Aklavik, Ft. McPherson, and Arctic Red River, and dairy cattle were kept at Aklavik during World War II (Robinson 1945: 30). Improvements in transport, combined with the effort required in family and uncertainty of the crop, have led to a general decay in agriculture, not only in the Mackenzie Delta, but also in the Mackenzie River valley as a whole, in the course of the last half century. In 1944, from Ft. Providence north, there were a total of between 50 and 60 acres of gardens and over 100 acres in farming (Robinson 1945: 38); today it is difficult to find land actively being cultivated apart from a few acres at Ft. Simpson. In 1910 there is supposed to have been even more land under cultivation than in 1944.

Another reason for this decline can be seen in current buying habits at Inuvik. Most government employees there either take the bulk of their food in standard government rations or buy it wholesale from Edmonton and have it shipped in by barge in the summer. In addition, the Canadian Forces base at Inuvik has fresh food flown in twice a month for its personnel and their dependents. Other government employees in the Delta are given a monetary allowance for fresh food to be bought locally, but with this exception most of the white population does not depend on local markets for most of their food. The low income of most of the native population leads them to buy as little food as possible in the markets; thus the food shipped in for the white population (and which does not pass through the local stores) represents a sizeable fraction of the food brought into the region. Not only does this raise local prices, but it reduces any incentive to experiment with agriculture.

There seem three broad means by which technology could help reduce the cost of food. Unfortunately, these apply principally to meats and vegetables; bulk foods - flour, sugar, tea - which form a large part of the native population's purchases do not seem likely at present to become cheaper except through a general cheapening of transport.

First, we have what may be termed the brute force approach and summed up in the question: is it really impossible to grow sufficient foods of various types in the Delta to meet local needs? The answer to this must be "no"; a great variety of vegetables have been grown there already, and with artificial aids such production could be increased. In northern Russia, great emphasis is put on self-sufficiency of this type, with a claimed high degree of success. The Russian experiments, however, would hardly appear to be economical: they use greenhouses and often lengthen the growing season with artificial light. As an example, at Noril'sk 300 kwh of electric power per square metre, in addition to heating, were used to grow 23 kilograms of tomatoes per sq. metre - or about 6 kwh per pound of fruit (Artem'yev 1963). On a profit making basis, this could hardly be practical in a region of high electric rates. A more promising approach has also been tried at Noril'sk (ibid.). This is the use of low grade waste heat from diesel generators to warm the ground in which the vegetables are planted. It is claimed that this triples or quadruples the crop, reduces the costs of production by a factor of three to four, and leads to a recovery of the capital expenses in two to three years. The cost and feasibility of such a scheme at Inuvik would be well worth investigating, though it has certain technical problems, such as the slumping of the earth from thawing of the permafrost, or, as the author of the Russian paper remarks, "geocryological factors must also be considered in the design of soil-heating systems in open fields".

A more modest but probably more feasible scheme would be to construct large greenhouses from sheets of transparent plastic. Calculations indicate that such devices should lengthen the growing season by offering protection against late spring and early fall frosts.[1]

A second broad approach would be to cheapen the cost of bringing food to the Delta. Here we come back to the question of reducing the costs of transport in general, which has been discussed in the preceding section. In addition, an effort could be made to grow vegetables in the nearest place where this could be done profitably and bring them to Inuvik from there. Ft. Simpson, some 600 miles up river, might be such a place; there has been an Experimental Station of the Department of Agriculture there for many years and truck gardening has recently been undertaken on a moderate scale. It would presumably be necessary to import fertilizer here, as to other places on the Mackenzie; still, the overall cost of such food in Inuvik, after having been brought only 600

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1. G.W. Rowley, pers. communication.

miles, should be cheaper than that brought from Edmonton, some 1700 miles away.

Another way of reducing the cost of bringing food to the Delta is to lighten the load that is transported. One naturally thinks of lowering the weight of foods by dehydration, as has long been done with such items as milk, orange juice, potatoes, and onions. A great deal else is also available in dehydrated (or in "freeze-dried") form, but, with certain exceptions like milk, the market for foods of this type is so low that they cannot compete with other methods of preservation; the added cost of production is more than the saving in freight costs would be.

A second way of making preserved foods lighter is to freeze them rather than put them in cans, and thus save the weight of the container. Here, of course, we have the question of storing the frozen foods once they have been brought to the Delta; we shall return to this presently. Further, bringing frozen foods to the Delta is an expensive process: it has to be hauled to Hay River by refrigerated truck and then shipped on a refrigerated barge. As a result, it costs \$13.22 to bring 100 lbs. of frozen food from Edmonton to Tuktoyaktuk. When we remember that, even in the south, frozen foods are considerably more expensive than the same foods in cans, we see that the small saving in weight is far from enough to make a cheaper product in the Delta.[1]

On the whole, it seems that the most promising way of reducing the cost of vegetables and such items in the Mackenzie Delta would be to combine bringing them from some place, like Ft. Simpson, which is comparatively near the Delta and yet has a sufficiently warm climate to make fairly risk-free farming possible, with the development of

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1. Another method of preserving food is by treatment with gamma radiation. This has appeared promising for several years now; currently there is concern about the long-term effects of the radiation in converting sugars into poisonous or carcinogenic compounds. It is best adapted to products like meat and butter, and it is not clear that its use would have any effect of the economics of life in the Mackenzie Delta, particularly if large scale frozen food facilities were available there.

local means of preservation. In this last the choice seems to lie between canning and freezing. The drawback with freezing is that there are no generally available means of keeping frozen foods. True, ice-caves, or holes dug into the permafrost, have been used for many years, both in Canada and in northern Russia (Mikhailov 1958: 266); more widespread use has been advocated from time to time (Copland 1956). Ice-caves have two drawbacks: they cannot absorb a large quantity of heat quickly and maintain a temperature below freezing - in other words it is difficult to freeze a large quantity of food in them - and their lowest temperature cannot be less than that of the ground in which they are dug. As we have seen, at Inuvik the ground temperature several feet below the surface is about 26°F; this is much too high for the long term storage of frozen foods, for which a temperature not above 0°F is recommended.

It should be possible to provide better storage facilities with a comparatively small amount of study and experimentation. One possibility is the use of a completely passive system - one which used the below-zero days of winter to freeze a suitable brine or other liquid which could be used as a heat sink for an insulated building for the warmer months of the year. Another method worth considering would be using the ground as a heat sink to reduce the temperature of a storage plant (or cave) to 26°F whenever necessary and then have a mechanical unit to chill it from there to 0°F.

Apart from the study of cheap means of keeping frozen foods, it seems that the possibilities of artificially lengthening the at Inuvik should be systematically investigated. Although, on the basis of present knowledge, large-scale farming there seems an unprofitable venture, this does not mean that the possibilities of growing food locally should be abandoned out of hand. They should instead be studied and encouraged to the fullest extent possible.

8. Medical services

When one considers the isolation of the Mackenzie Delta, the medical services available there seem, to a layman, to be of high quality. This isolation does, nonetheless, limit medical care in several ways, and it is interesting to explore the effectiveness of modern technology in counteracting this.

Medical care in the region is centred around a hospital at Inuvik with satellite stations - "nursing stations" - in the smaller settlements. By southern standards, the Inuvik hospital is quite large for the region it serves - it has 100 beds for the approximately

7000 inhabitants of the Inuvik Zone.[1] It is modern and well-equipped: large rooms, good laundry service, full x-ray facilities, and a chemistry laboratory. One technical problem in southern hospitals, maintaining an adequate record facility, is somewhat less troublesome here, since the area served is so large that the native population generally remains inside it.

The nursing stations - there are three within the area covered by this report, at Aklavik, Ft. McPherson, and Tuktoyaktuk - are each staffed by one or two nurses, and also have comparatively full equipment, including x-ray apparatus. Due to the limited distances between the settlements of the Delta, it is possible to get seriously ill people to hospital by aircraft on very short notice.

In this situation technology can contribute by increasing the number of channels of contact, not only within the region, but also with the rest of the world. One way is the use of aircraft; in addition to their use within the Delta, the more seriously ill patients and some cases where diagnosis is difficult[2] are taken to hospital at Edmonton by air.

Another is the establishment of a radio net. Though telephone service links all the nursing stations of the Delta with the Inuvik hospital, calls are expensive enough that its use is avoided; efforts at setting up radio communication, as is done in the eastern Arctic, have not met with conspicuous success. Here it seems a little study and encouragement might provide a means which, at moderate cost, could provide doctor's advice quickly in more cases than only those meriting emergency treatment.

On a larger scale, a radio or telephone net might be set up linking the hospital at Inuvik with others in the south. This would be an extension of what has been done in rural districts in the south, such as around Albany, N.Y., U.S.A. (Woolsey 1960). There it has

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1. The zone extends east to Paulatuk on the mainland and to Sachs Harbour on Banks Island, west to Herschel Island and Old Crow, and south to Ft. Norman and Ft. Franklin. It therefore comprises a much larger area than the Mackenzie Delta.

2. In 1964, a total of 43 patients for both categories were sent south (Dr. J.H. Rooks, pers. comm.).

proved a useful means of post-graduate training, which is always important in medicine. In fact, such two-way radio communication has proved so successful in allowing exchange of information and experience that, in one instance at least, it has been supplemented by television (Woolsey and Strauss 1964), with complete success.

Technology can make technical advice, too, more quickly available. In particular, here, we have the matter of specialists. Because of the small total population of the Inuvik region it is not feasible to have specialists of many types in residence; thus, there is no cardiologist, pathologist, or radiologist at Inuvik. If expert advice is needed in the interpretation of an obscure x-ray, the plate has to be sent to Edmonton by mail. This can mean up to a week's delay. Similar problems can arise with electrocardiograms and biopsies.

The land line can help in many such cases. Electrocardiograms are now routinely sent over telephone lines. The problem of transmitting x-rays has been under study at the Walter Reed Army Medical Centre, Washington, D.C., U.S.A. Currently they send x-rays over a closed-circuit television system linking various parts of the medical centre and some other hospitals in the area; no difficulties have been found either with resolution or with contrast. In principle, x-rays could be transmitted by a facsimile process, since the advantages television has with its higher frequencies and broader bandwidth can be considered as the ability to transmit many pictures in a short time, which is not necessary in dealing with x-rays. Difficulties may arise in using commercial equipment in such an application; this side of the problem is under study.

In the future, it may be possible to use similar means to transmit coloured images of slides for pathological studies. Here the principal difficulty at present lies in maintaining fidelity of colour; in other words, in ensuring that the transmitted image is true to the original. This ought to be solved in time; in the meantime, the ability to transmit x-rays would be a considerable advantage in itself.

It would be interesting to study the possibilities of such technological aids in more detail. Nevertheless, even this superficial survey shows how exploiting such possibilities could provide improved medical services in the Mackenzie Delta. This in itself is always a desirable goal; the fact that its attainment would probably be accompanied by reduced running expenses makes it doubly so.

9. Conclusion

In the last chapter of this report we shall bring together the various suggestions for further study that have arisen in the course of the above discussion. Here we shall only point to a general overall pattern: we have found, time after time, that life with a "southern" level of amenities is expensive in the Mackenzie Delta because of the small number of people. This agrees with our initial observation that these amenities are cheap - or even available at all - because they can be produced and used in large quantities. It underlines the importance of pulling the settlements of the region together and trying to make the distribution of facilities within the area both cheap and simple.

Specialized research is also needed in many areas; examples are the study of the possibilities of extending the growing season for plants or that of the difficulties of underground water supply systems. The central problems, however, remain those that arise from the fact that the natural conditions of the Mackenzie Delta force the population to be dispersed. Thus cheaper transport, better means of transmitting power, and the like remain the most important goals. Reaching these; accepting the dispersal of the population and finding ways to link it together: this is the way in which technology can ensure the economic development of the area.

IV

Technological Aspects of Camp Life

In the last chapter we discussed technology as it applies to living in the settlements of the Mackenzie Delta. As we have remarked before, however, a large part of the native population may spend months at a time living in individual camps outside these settlements. Although there is a decided trend toward living in the communities, any exploitation of available renewable resources will continue to require some living in these isolated camps for the foreseeable future. In this chapter we shall consider ways in which technology might make such a life less labourious and less isolated.

Much of what we have said earlier applies to camp life as well. For example, the type of life led there relies on surface transport; here we need only remind the reader of the need for some sort of year-round transport to relieve the isolation of these camps, particularly during break-up, and for a cheap, reliable form of mechanized winter transport. Again, housing and heating are subjects where what we have already considered applies equally well to individual living. We may add here that the nature of the Delta is such that almost every camp can be reached by a fairly sizeable boat if there is any need to bring materials for building or the like.

Another subject of interest is the provision of better water and sewage facilities at these camps. Water is generally available. Sewage and waste disposal at an isolated place are, naturally, much less serious problems than they are in the settlements of the Delta. Furthermore, there are many schemes for leaching pits and individual sewage disposal systems that have been specifically designed for a northern environment (Yates and Stanley 1966: 415; Grainge 1965). One or another of these might be useful in making camp life more strictly comparable with that in a town.

Of more importance is providing electricity in one of these isolated spots. Diesel or gasoline generators are, of course, available in small sizes, but they are comparatively expensive to run. More intriguing is the possibility of using the direct conversion of heat to electricity. By nature this is an inefficient process. The simplest devices - those operating on the thermo-electric principle - typically

achieve efficiencies of one to two per cent; more sophisticated solid state devices (which produce power at a low voltage and require considerable additional apparatus to be useful) may reach 5% to 10% efficiency at present. Since the theoretical maximum efficiency obtainable, in the vicinity of 30% (Heikes and Ure 1962: 536), is no better than that of the diesel generators in the Delta communities, this process offers little promise of replacing them. But an individual cabin is another matter. It must be heated; a device which converts a small part of that heat to electricity would be of great use. Simple calculations show that, on the basis of a 5% efficient system, a stove burning $2\frac{1}{2}$ gallons of oil a day could produce 200 watts of electric power. This would not run mechanical equipment, but it could power an electric light and a radio or short-range transmitter. These alone should ease the isolation of the life, and an investigation of the practicability of such a system would be well worth-while.

Such an independent supply of electricity would also be useful in providing another means of reducing the isolation of these camps: some form of emergency communication. At present, if an emergency arises at a camp, it may well be virtually impossible to send out a message for help. As people tend to live more in settlements they may become less familiar with this feature of an isolated life; this may be a contributing factor to the decline of trapping with its resultant decline in the cash economy of the Delta. Serious consideration has been given to this problem of providing emergency radio communication (see, for example, N.W.T. Council 1965: Vol. I. 400 ff; 1966: Vol. I, p. 970), but such devices have not yet become standard.

A major problem is finding means of powering such emergency transmitters. Conventionally, this is done with batteries, which suffer from the fault that they cannot deliver much energy when they are cold; their shelf life also grows shorter in cold weather. In short, they are not particularly suited to providing emergency power in places that are unheated for long periods. Here some means of directly converting heat to electricity would be very useful, for it would depend only on getting a stove burning, and would not deteriorate in cold weather.

Such an emergency service also has the problem of choice of frequency. In the arctic, almost every radio frequency is subject

to signal fading and periods of complete blackout. Here the Mackenzie Delta seems to have a considerable geographical advantage. By using the mountains and hills which surround the Delta, it should be feasible to select a few sites which would allow line-of-sight communications with the whole area. Then VHF transmission could be used, which should provide minimal trouble with auroral disturbances.

In short, apart from the issues raised in the last chapter, technology seems most able to help life in the camps of this region by providing a means of generating at least a small amount of electricity cheaply and a reliable form of emergency communications. The above suggestions are only one way of doing this; the overall problem remains an interesting field for development.

V

The Exploitation of Renewable Resources

So far we have been concerned with technology as an aid in providing the amenities of life. It can also make a contribution to the exploitation of renewable resources; in the long run this is of equal, if not greater, importance. The situation in the Mackenzie Delta is such that we can give only the barest outline of possible technological contributions. This is still well worth doing and forms the subject of the present chapter.

The basic renewable resources of the region are the tundra, the forests, the wildlife, and the fish. Of these, the first forms the basis of the reindeer herding industry, which is beyond the scope of this paper. The furs of the region are well-known; for many years they formed the basis of its economy. The fishing is of a low grade compared with what is available in the south; the same is even more true of the forests. Nevertheless, when there are so few resources one cannot afford to disregard anything, and each of these should be studied to see how it can be developed as far as possible.

At first glance, the forests of the Mackenzie Delta are unpromising. The trees are small, grow slowly, and have a large number of branches near the ground. Lumber cut from them has many knots and only uses a comparatively small fraction of the volume of wood. These forests, however, contain the only substantial stands of timber north of the Liard River; as such, they are the nearest source of lumber not only for the Mackenzie Delta but also for much of the western arctic. Professional opinion (Forestal 1965) holds that many of these trees, particularly around Arctic Red River and Ft. McPherson, are of commercial value. A small saw-mill, currently near Arctic Red River, has been maintained for several years. Its lumber has been used for various types of rough work and for low-cost housing. Wood from this mill is presently (1967) commercially available in Inuvik.

Technology can contribute to the utilization of this resource in two ways. In the first place, as we have mentioned above (p. 36), the wood might be used for various wood-plastic combinations and thus produce a lumber substitute of higher quality than the present product with higher utilization of the wood.

Second, technology may well be of use in improving the local forests. It is difficult to go into any detail here, since the forestry problems of the area have not been studied at more than the most superficial level. Present practice is to treat the forests as a non-renewable resource, on the ground that the trees grow too slowly, but this does not seem true. The growth rate is indeed slow - somewhat less than half as fast as it is around Ottawa, as a rough guide - but even at a fairly high current rate of usage it should be quite possible to renew the trees cut in the region.

Furthermore, very little is known of the factors influencing the seeding and growth of trees in the region. A mossy cover is believed to inhibit the seeding of new trees, but even this is not certain, and the whole matter is bound in closely with the highly debatable question of what factors determine the exact location of the tree line. It is clear that, here as always, technology can only make a subsidiary contribution to that of basic research. Studies have first to be made to ascertain the exact influence of the ground cover on the growth of trees; then technology may be able to help in providing the most favourable conditions. With due care, there seems no reason why the forests of the upper Mackenzie Delta cannot be used, and used with profit, for many years.

Trapping - utilizing the wildlife resource - raises difficult sociological problems, which are outside the purview of this paper. It has, of course, been a traditional occupation for the last century; the most common fur-bearing animal is muskrat, with mink being of secondary importance (Black 1961: 66). Other animals - lynx, beaver, marten, and fox - also are taken. In recent years, with increased wage employment, trapping has declined; nonetheless, it remains one of the principal ways by which money is brought into the Delta. Its future position, however, must (to quote the report of the Committee on Manitoba's Economic Future)

> "be examined carefully from the point of view of its overall social consequences"

for

> "reversion to, and the strengthening of, the more primitive type of social organization and work habits which characterize trapping may not be desirable....although from the point of view of providing increased income and employment, trapping is an enterprise capable of expansion". (Comm. on Manitoba's Economic Future 1963: pp. V-5-3 f.)

If we assume that trapping is to be encouraged - and further, what is hardly true at present, that it is carried out in the most businesslike manner practicable - then there are various ways in which technology can help to produce and maintain the maximum amount of income from wild furs. First, fairly simple technical means - building dams and the like - might increase the number of muskrat living in the area. This possibility was suggested several years ago, and a few dams were built, of which one has remained intact and seems to improve the environment. In general, though, trapping of existing muskrat seems to be done in such an inefficient manner that it seems premature to consider means of increasing their numbers.

Second, efforts should be made to reduce the amount of labour associated with trapping. One way would be to provide better means of transport, as has already been discussed; in the present connection this would allow a man to have a longer trap line and a resultant larger catch of high quality furs. Furthermore, the present way of preparing pelts is quite primitive, and they are often damaged or insufficiently cleaned. It might be possible to devise ways of improving and simplifying this work, which would again lead to higher quality skins and at the same time lessen the labour expended.

A third possible application of technology is in the local tanning of skins. Although a considerable amount of handicraft work with fur is done in the Delta, in the past the skins used have been procured from southern Canada. In the summer of 1966 a tannery was started at Aklavik to provide furs for local use. The value it should have in improving the cash basis of the economy is clear, though the quality of the furs produced in the first season's work was such that it is also clear that there will have to be considerable technical improvement in the tanning before it can come up to expectations.

Finally, we come to fishing. This is, in a sense, a complimentary occupation to trapping, and, in the Soviet Union, there have been attempts to combine such seasonal occupations to provide suitable year-round employment which can compete with conventional wage-earning occupations. Though it seems that this practice should be encouraged in the Mackenzie Delta, attempts to catch and export fish are currently limited to those organized by a commercial company from southern Canada.

The state of fish as a continuing resource is even more poorly known than is the case with the forests. Little, if any, work has been done on the vital question of how large a catch can be taken from either fresh water or from the ocean without depleting the stock. In this situation, we can only make a few general comments on fishing as practiced in the region and on developments in the field elsewhere.

The situation in the Mackenzie Delta seems similar to that found in the great Russian Rivers. There, though it is realized that, as in Canada, fisheries at the northern river deltas cannot compete in volume with southern regions, their importance is stressed (Mikhailov 1958: 204). In northern Russia, as in the Mackenzie Delta, the methods used in fishing are primitive; technology - perhaps, as an example, the use of sonar to locate fish - could help in bringing these up to date.

Another approach that might be used in the future can be described as the scientific harvesting of fish as a continuing crop. The general approach may best be seen by giving an example. It has been found that tuna tend to congregate over underwater hills where there is a natural flow of nutrient. As the fish grow, they tend to move to another hill whose top is farther below the surface. They can be kept in a given vicinity by improving the flow of nutrient; within ten to twenty years it may also be possible to keep them in electronic pens. If this can be done, and means devised for moving the fish from one pen to another, then we can hope to see commercial tuna fishing on much the same pattern as, on a far smaller scale, trout are now raised in fish hatcheries.

It is, of course, open to serious question whether the Mackenzie Delta could support fisheries on the scale that such - presumably costly - equipment would demand. Here again, as with the forests, much basic research must be done to learn the detailed habits of the local species of fish, how much can be harvested without depleting the stock, and also the most efficient way of maintaining this stock. It may then prove possible, by using technological aids and approaches developed elsewhere, to increase the income from fishing substantially and to ensure its availability on a continuing basis. Of the methods of exploiting renewable resources that we have mentioned, this may well be the furthest off in time, but it may also prove to be the most profitable.

VI

CONCLUSION

In this report we have considered two general areas in which technology could improve the standard of living of the native population of the Mackenzie Delta.

The first comprises the ways in which technology can directly reduce the cost of living in the area - or, in other words, make more of the amenities of life in the south available to the native population. As we have seen in the survey of Chapter III, many of these amenities are available in the Mackenzie Delta, but at a cost which more or less limits their enjoyment to government workers, who are typically from the south. In the simplest terms, this high basic cost of utilities arises from the remoteness of the region and its small population as compared to more southerly places. Although some avenues of investigation have been pointed out in the course of this survey and will be summarized below, it appears that in most instances the basic framework within which technology can work is known, and the most economical of present-day solutions is in use.

Here we can hope for some radical development in one or another field of technology - a new, compact, cheap source of heat and electricity, for example, or a cheap, reliable means of year-rou transport - but, barring such, the best hope for reducing the cost of living lies in continuing, patient refinement and improvement of what is already available and continuing investigation of ways of making more efficient use of what is available (an example of this is utilizing the waste heat from diesel generators). This approach is far from glamourous, but if pursued over a period of time could lead to a significant improvement in the native standard of living.

Second, we have briefly considered the possibilities of technologically aiding the utilization of renewable resources, and improving the cash economy of the Mackenzie Delta in this way. This field seems to hold considerable promise; at present, however, there is a lack of basic research and of an understanding of the limits to which these resources can be harvested on a continuing basis. In most instances, it is impossible now to give more than an outline of the possible ways in which technology might aid in the harvesting of these resources on a continuing basis.

In conclusion, we can list the various subjects that we have noted throughout this report as providing interesting possibilities for further study. Most of them can be put into three groups: studies where some technological research or development seems required; studies of matters where the technological problems seem fairly well understood but where the question is of economic feasibility, and subjects where basic scientific research is necessary.

First, we have come across a few points where existing technological research and development seem inadequate:

1) Methods of constructing all-weather roads on silt and permafrost, as occurs at Aklavik, with the use of a minimum of imported materials;

2) Reliable, economic oversnow vehicles and vehicles for year-round use;

3) The development of a compact, reasonably efficient device to convert heat to electricity at a reasonably high power level (say a few hundred watts);

4) Methods of using the waste heat from diesel generators, particularly feasible ways of warming the ground for agricultural purposes;

5) The long term properties of insulating materials - including the possibilities of using moss as an insulator, the long term resistance of expanded polymerized plastics to moisture in underground applications, and the practical value of expanded plastic insulation made with inert gases; and

6) The development of technological aids for the exploitation of renewable resources. This last includes many points, ranging from finding the practical value of wood-plastic combinations through studying methods of encouraging the growth and seeding of trees to studying possibilities for increasing the muskrat population and increasing the efficiency of fishing.

Second, there are several subjects where the emphasis is primarily on the economics of the situation:

7) The costs and probable effects of a network of roads or

winter roads within the region, both by itself and in conjunction with a road from the south, as the one currently under study;

8) The possibilities of using electric transmission lines between some or all of the settlements;

9) The long-term potential of a hydro-electric installation; and

10) The practicability and usefulness of freezing plants, either passive ones or ones using the ground as a heat sink.

Third, we have seen two main fields in which basic research is needed:

11) Forestry, where the mechanisms influencing the seeding of trees are not fully understood, and

12) Fishing, where detailed knowledge of the stocks of fish, their rates of reproduction, and their habits are essential to any sensible attempt at their continuing exploitation.

Finally, there are a few subjects, as always, which do not fit into any scheme:

13) The possibilities of improving medical services by using communications techniques to their fullest should be pursued;

14) Ways should be found to encourage the local market for fresh food; and

15) Means should be sought out to encourage local building construction with the greatest practical use of local materials.

Such a list, of course, is not complete, and the subjects given are of vastly differing importance. Still, it serves to show the variety of problems and the degree of imagination needed in the man who would contribute to the development of an arctic region like the Mackenzie Delta.

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